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Reorganization of the light and heavy repairs of goods vehicles on the Belgian Railways [1],

by Mr. WARTE,

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Figs 1 to 9, pp. 1654 to 1669.

The reorganization measures adopted by the rolling-stock department of the Belgian Railways during the early months of 1929 gave such good results quickly that we consider an account of them may be of interest to those who, in the various railway systems, are responsible for maintaining and repairing goods vehicles.

In order to be effective, a description of an organization method should enable the reader to make comparisons with a similar problem he himself may have to solve. It is in order to make such comparisons possible that it is of interest to give first of all some general information on the rolling stock problem, as it exists on the Belgian Railways.

CHAPTER I.

General information.

A. — Goods traffic.

a) *Nature and amount of the traffic.*

The following table shows for the year 1929 the amount of tonne-kilometres (of ton-miles) for important categories of goods:

Nature of the goods.	T.-km.	(E. ton-miles in 1928 (in millions)
Fuel	2 638	(1613)
Metallurgical products	1 371	(839)
Ores	1 047	(640)
Sundry	2 752	(1683)
	7 808	(4775)

The diagram, figure 1, shows the subdivision of the traffic handled by the Belgian National Railways on their various lines.

The thickness of the strokes is proportionate to the number of trains passing over the lines shown.

b) *Turn-round time of the vehicles.*

The average turn-round time of a goods vehicle was 4.6 days in 1928.

The average number of wagons loaded was 21 147 per working day in 1928.

c) *Shunting in stations.*

Shunting of wagons in the large goods-stations is done by gravity, the wagons

(1) Translated from the French.

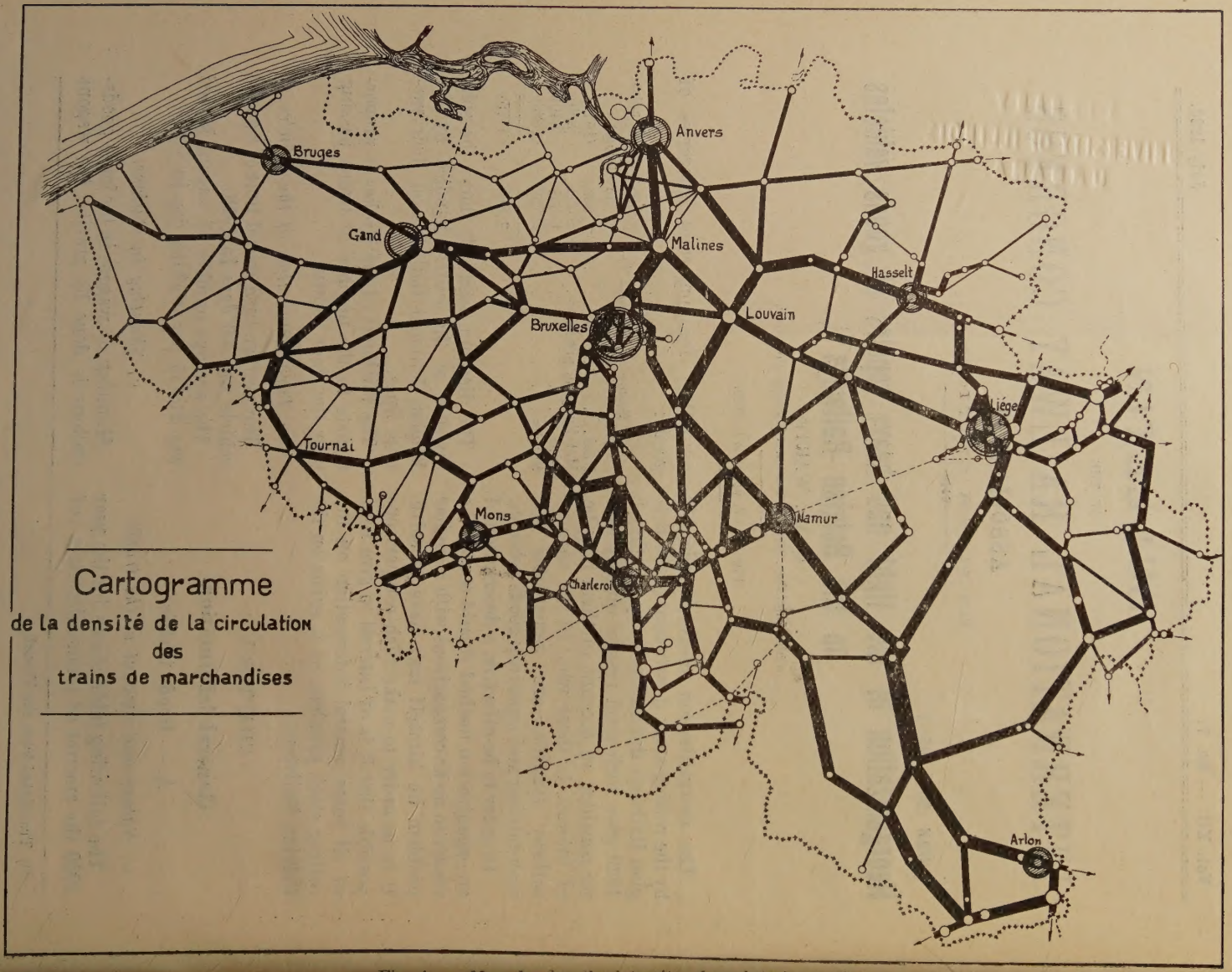

Fig. 1. — Map showing the intensity of goods-trains traffic.

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being stopped by means of Büssing skid brakes.

The average rate of shunting is 200 wagons per hour.

d) *Heavy traffic seasons.*

Each year, the Belgian railway system has a period of heavy traffic. This period, which runs from 15 October to 15 November, is notable for the heavy demand for covered wagons and specially for open trucks for the carrying of beetroot and coal.

The diagram, figure 2, shows the weekly trade requirements of vehicles.

B. — Rolling stock used.

The following table shows the amount of goods vehicles available on 31 March 1929, classified according to the kinds of trucks:

KIND OF VEHICLES.	Number.	Average age on 31 March 1929.
Guard's vans	2 474	20 years.
Closed vans, 5 tons.	25	30 —
— — 10 —	2 830	40 —
— — 12 —	107	37 —
— — 15 —	29 102	17 —
— — 20 —	2 289	11.5 —
Cattle wagons	4 577	25 —
Total.	38 930	
Open wagons, 10 tons	4 530	45 years.
— — 12 —	3 829	46 —
— — 15 —	24 363	22 —
— — 20 —	31 274	12 —
— — 25 —	1 661	21 —
Total.	65 657	
Flat wagons, 2 axles, 10 tons	1 007	40 years.
— — — 12 —	160	35 —
— — — 15 —	5 727	19.5 —
— — — 18 —	27	15 —
— — (bogies) 20 —	1 473	26 —
— — — 25 —	75	36 —
— — — 30 —	72	15 —
— — — 35 —	651	16 —
— — — 40 —	898	4.5 —
Sundry	222	
Total	10 272	
Sundry special wagons, of which 1 029 leased to the Ferry Boats Service	5 831	20 years.
Making in all	123 164 wagons.	

The average life of these wagons is 22 years, and the estimated renewal period of 40 years is exaggerated. As a matter of fact, very few orders for new wagons have been placed since the armistice. In order, therefore, not to run the risk of having some day to place mass-orders for new rolling-stock, the existing

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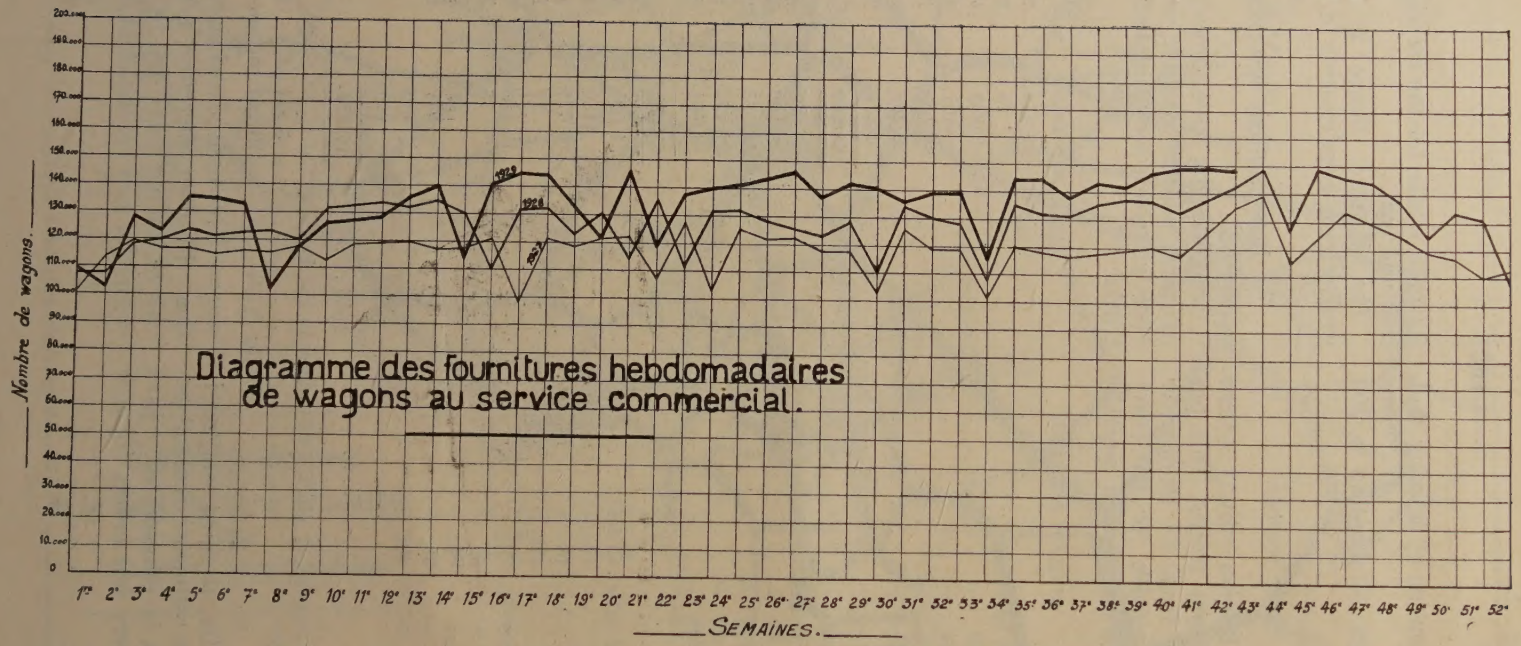

Fig. 2. — Diagram of weekly supplies of wagons to the commercial service.

Explanation of French terms: Nombre de wagons = Number of wagons. — Semaines = Weeks.

stock had to be « freshened up » following a systematic programme of repairs, taking into account renewal orders which, as we shall see further on, it has been possible to limit owing to the measures taken.

C. — Staff employed for the maintenance and repairs of rolling-stock.

The rolling stock is maintained and repaired solely by the staff of the Company.

This work was done (up to 30 August 1929):

1. by 1 168 examiners who, apart from inspection work, are entrusted with small repairs to wagons. The men appointed to examine passenger carriages are included in this figure of 1 168;

2. by 230 workmen employed in the repairing shops at stations;

3. by 28 sectional workshops employing in August 1929, an average of 15 058 hours per day of labour, or 1 884 hands;

4. by 4 central wagon-repairing shops which employed in August 1929 a daily average of 19 000 hours of labour, or 2 383 hands.

The geographical situation of these various shops is shown on the diagram, figure 3.

D. — Plant.

1. *Maintenance shops.* — The men working at these depots work in the open air, on one or more tracks specially kept for this purpose in the large goods stations. These maintenance depots are only fitted with a small forge.

2. *Sectional shops.* — The construction of these shops is usually sufficiently spacious to enable the men to work under cover. The tracks in these shops are long enough to place on them a larger number of wagons than the daily output.

Some workshops — generally the most recent — have double entrances; most of them only have a single entrance.

The equipment of these shops is fairly complete; most of them have:

a lathe for returning tyres;
a lathe for turning up axle journals;
a centring lathe;
machines for planing, drilling and boring bushes;
a steam-hammer with a 200-kgr. (440-lb.) hammer.

Most of them have woodworking machines, and even four-face planing machines.

The wagons are usually lifted by electrically driven jacks.

3. *Central workshops.* — These are fitted with all the latest wood and metal working machinery and handling plant in proportion.

CHAPTER II.

A summary description of the old organization.

I. — Wagons out of service.

Wagons which are damaged had « not to go » labels put on them by the examiners or by station masters (or their delegates) at stations where there is no examiner.

There were four main kinds of labels:

a) *White labels* with a red line across them, indicating that the wagon was to be repaired at one of the station repairing shops, when the damage was only slight and for which the principal work was that of dismantling and re-assembling which is usually done in 3 hours.

b) *Yellow labels* meaning that the wagon was to be sent to one of the sectional

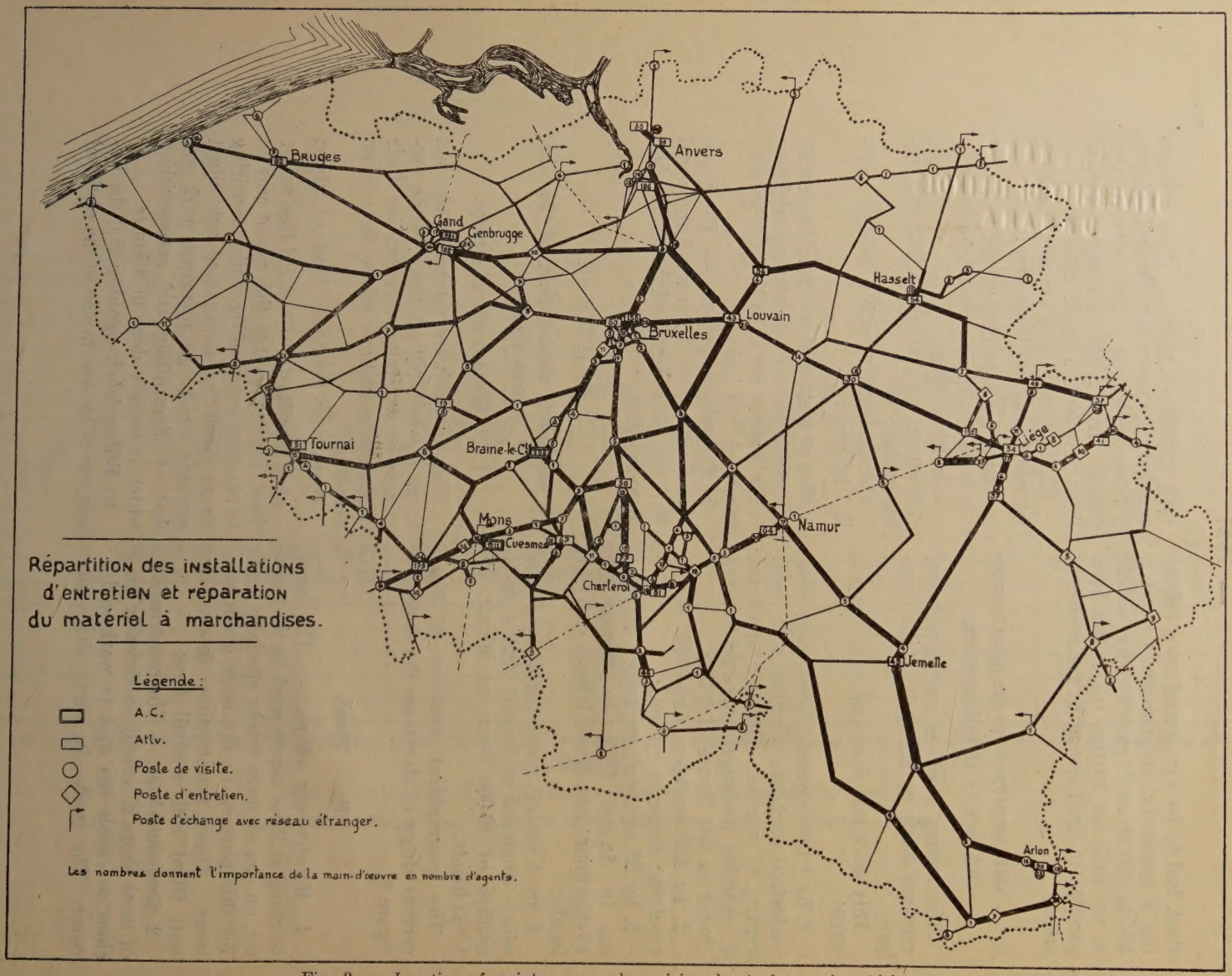

Fig. 3. — Location of maintenance and repairing depots for goods vehicles.

Explanation of French terms: □ = Central workshop. = □ = Sectional workshop. -- O Examining depot. — ◇ Maintenance depot. —

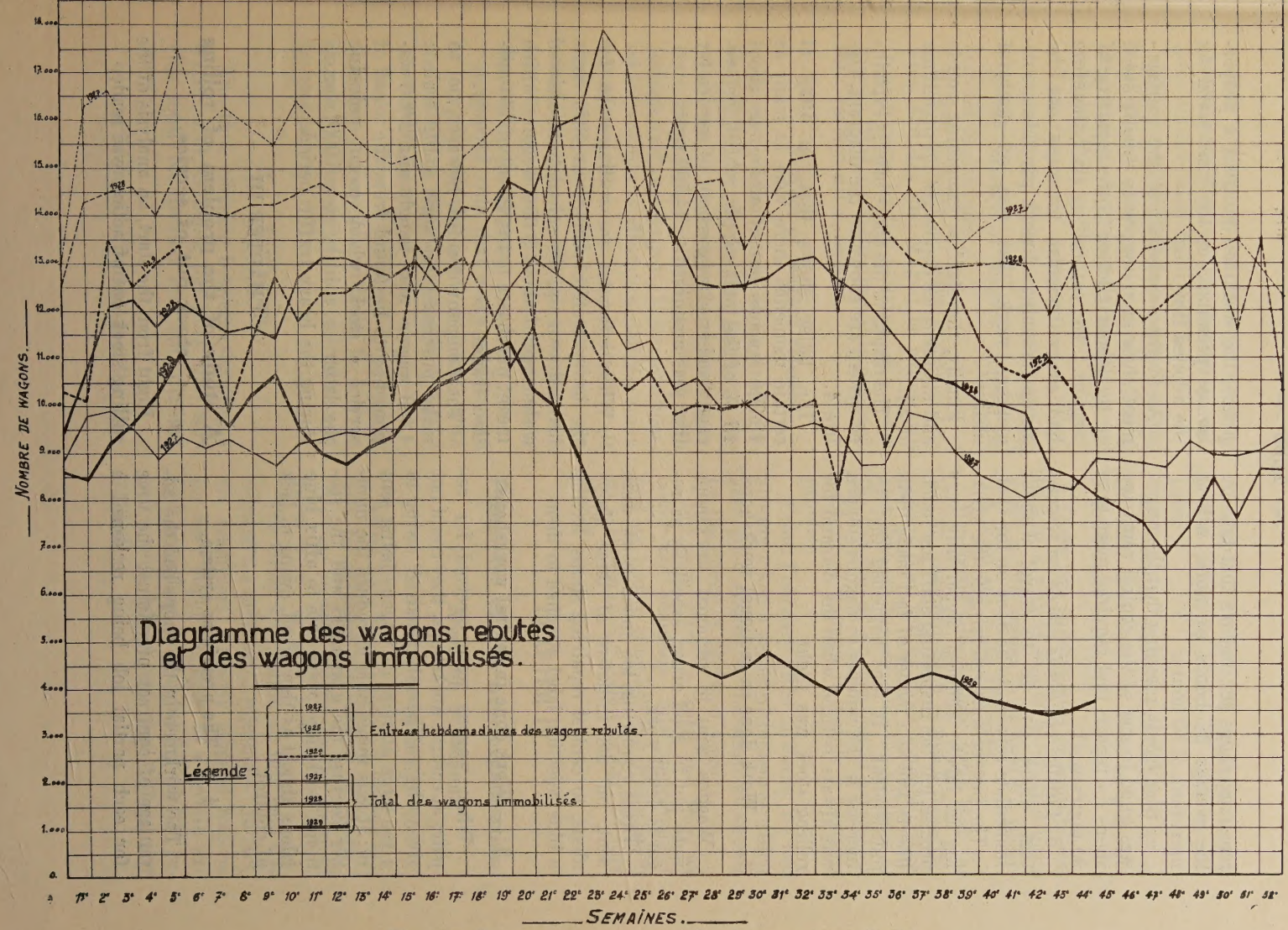

Fig. 4. — Diagram of wagons rejected and wagons immobilised.

Explanation of French terms: Entrées hebdomadaires des wagons rebutés = Weekly entries of rejected wagons. — Total des wagons immobilisés = Total of wagons immobilised.

repairing shops for repairs that take on the average 25 hours of work, with a maximum of 80 hours.

c) *Blue labels*, meaning that the wagon was to go to one of the central repairing shops for repairs that required more than 90 hours work.

d) Finally, *red labels* placed on wagons that where not fit to travel without immediate repairs, to be done on the spot.

The instructions referring to the affixing of labels, although apparently very precise, left the inspecting staff too much liberty and as a matter of fact made them independent. It thus happened that an increase in the number of wagons stopped was always noticed when the demand for rolling stock was slight.

2. — Work done in sectional workshops.

Wagons sent to sectional workshops were put in good order, especially as regards detail work.

Those requiring too much work were sent, on the initiative of these shops alone, to central repairing shops, having a blue rejection label attached to them.

3. — Work done in central workshops.

When wagons were received for repairs at central workshops, they could not always be sufficiently repaired, owing to a too large number of wagons being sent in; it was impossible to reduce the number because the examiners and the sectional workshops were able to affix blue labels almost as they liked, owing to lack of control.

4. — The premiums system.

The workmen in the shops had the advantage of contract premiums: the time for each partial job being reckoned à priori, the workman received a proportionate premium for the time saved on the allotted time.

As to the overseers and the management, their premiums were usually based on the labour allotted to the repairing of wagons. The controlling staff therefore had every incentive to carry out the greatest amount of work possible — sometimes work that was of doubtful utility.

Finally, the staff at examining points and maintenance depots got no premiums at all.

The results of the above briefly explained system are shown in the diagram, figure 4.

The latter shows that, in 1928 at certain moments, there were as many as 18 000 wagons out of action, or about 15 % of the total supply, whilst the average number of wagons out of service for that year amounted to 11 700 units.

* * *

When estimates for rolling-stock for the heavy traffic periods in 1929 were being drawn up, the calculations showed a shortage of about 3 000 wagons, which meant purchases to the extent of 150 million francs.

The Company decided, however, not to make purchases on such a big scale : 1 100 wagons were bought and 2 000 wagons had to be found from the « out of service » stock, which meant reducing the latter to a little over 5 000 wagons during the heavy traffic period.

CHAPTER III.

A study of the problem of rolling stock out of service.

Right from the start, an analysis of the rolling stock out of action was made.

This laying up of rolling stock is shown, each day, by the number of wagons immobilised from traffic.

This number therefore comprises the total number of wagons rejected, whether they were at stations, in trains or in the workshops.

Two important factors have an influence on the extent of the laying up :

A. the number of wagons stopped on account of damages :

B. the number of days elapsing between the day the wagon is withdrawn from service, by the affixing of a « not to go » label, until the time it is put back into service after repairs.

A. — Number of wagons rejected.

In view of the nature of the traffic to be handled by the Belgian Railways, the small area of their system and the numerous interchanges of rolling stock with foreign railway systems, it was considered impossible to allocate a definite number of vehicles to our interior traffic. If such a measure had been practical, we could have made special arrangements for our interior traffic and thus reduce the causes of stopping.

A general rule that every vehicle had to comply, at any given moment, with the conditions imposed by the R. I. V. had however to be made.

Under these conditions, any vehicle that does not comply with the R. I. V. or is not quite up to its booked load has to be stopped.

B. — Laying up.

The time elapsing between stopping a wagon and its being put back into service must be divided into two distinct parts :

a) traffic-immobilisation, i. e. the time necessary for a labelled wagon to arrive at the workshop entrusted with its repairs :

b) rolling stock-immobilisation, i. e. the time necessary for it to be put into a good state of repair.

These two subdivisions of immobilisation of a wagon should be studied quite apart, as the means to be used for reducing them are quite different.

We would add straight away that the traffic immobilisation is much more important than rolling stock immobilisation and that on this account, the problem of the number of wagons out of service on account of damage is mainly a working problem.

From February 1929 onwards, we had already taken a series of measures which gave good results at the start, as shown by the curve of damaged wagons.

But soon after, in April and May, we could not maintain this improvement and we had to complete the organisation as is shown in the following part of this article.

CHAPTER IV.

Principles of the new organisation.

1. — Rejection of wagons.

a) *As regards quantity.*

As we have shown above, a vehicle can only be rejected for reasons of safety : either as regards traffic, in the sense of the R. I. V., or as to load.

The strict application of this rule has reduced the number of rejections : in fact, the examiners formerly stopped wagons for very slight damages, to a certain extent according to commercial traffic requirements, but in any case without any method.

On the other hand, among the wagons composing our rolling stock, we were able, by means of statistics, to find out which were defective types, subject to frequent damage, always of the same nature, and requiring the most maintenance. It was then logical to withdraw these vehicles from all traffic during normal periods, i. e. from January to the end of September. That was the reason for forming the reserve depots (garage R.).

From a certain period, therefore, and in accordance with instructions given twice a month, by means of a fortnightly bulletin issued by the central rolling stock authorities, worked out in conjunction with the central operating department, the examiners or workshops send to depots at certain stations named, on lines usually used for storing superflous rolling stock or reserve material, the wagons indicated in the fortnightly bulletin.

These depots are specialised for housing covered wagons or open top wagons. They are spread about the railway system, taking into account not only spaces available but also the probable places of demand when heavy traffic arises.

The map, figure 5, shows the localities adopted in 1929 and the maximum capacity of each storage depot.

The wagons housed there must be in a fit state for traffic. They have affixed to them a large letter R painted in white, so as to avoid their being taken into use before an order has been issued by the central rolling stock authorities. All examinors have, in effect, received orders to stop any wagon bearing the aforesaid letter R from being used for traffic purposes.

On the 30 August 1929, the date from which covered wagons were progressively withdrawm from these depots, there were 9 700 wagons stored, of which 4 600 were covered wagons and 5 100 open top wagons.

The putting into service of the R wagons is done according to a schedule drawn up by the rolling stock department in such a manner that these wagons may, as far, as possible, go to a repairing shop before being handed over to commercial traffic. This precaution seemed to be indispensable to avoid defects arising from being garaged for long periods. The number of wagons to be sent periodically and by predetermined trains to a repair shop was fixed so as to avoid any blocking up.

b) *Stopping of wagons as regards quality.*

So as to avoid an excessive forwarding of wagons to central workshops, examiners and the sectional workshops can no longer send wagons to central workshops.

Vehicles which the sectional workshops consider too seriously damaged to be repaired by them — a condition which is usually estimated by fixing at about 120 hours the work to be done by the builders and carpenters' gangs — are collected in a few important sectional workshops specially appointed for this purpose.

Officials from headquarters visit the latter periodically and pick out those wagons which it appears justifiable to send to central workshops.

This method of procedure has enabled us to reduce very considerably the number of wagons immobilised at central workshops. Whereas on the 8 May 1929, the number of wagons out of service for repairs at central workshops was 4 669, it was 2 930 on June 1929 and 1 355 on 8 July 1929.

The supplying of the central workshops by a special travelling committee has numerous and important advantages : creat-

Fig. 5. — Distribution of « R » depots.

Explanation of French terms: ○ Covered wagon depots. — □ Open top wagon depots.

ing a large stock of damaged wagons is thus avoided; the wagons to be repaired are chosen judiciously, in proportion to the capacity of the workshops and, finally, a systematic supply to them is obtained, which enables them to work on mass-production lines and better specialise the labour.

We should mention that a consequence of the reduction of immobilisation for the central workshops is that certain extension works, which were considered as indispensable until quite recently, can now be definitely abandoned and this has already saved an outlay of several million francs.

B. — Immobilisation at the expense of the operating department.

In order to accelerate the forwarding of stopped of wagons to the repairing shops, we created for each station a forwarding register, viz. a classification according to which each station master knows to which destination and by which train he has to send a wagon of any particular type that is standing damaged in his station.

This form, shown in figure 6, takes into account not only the different kinds of damage sustained by the wagon but also the streams of traffic, thus enabling the wagons to be sent on, as far as possible, following their natural course.

For instance, a station A, situated between two repairing shops B and C, will send damaged covered wagons to B if B is a centre using covered wagons or if B is situated in the direction of a centre normally using covered wagons coming from station A.

For the same reasons, open top wagons can be sent to repairing shop C.

The stations in the neighbourhood of repairing shops have more detailed forms: on these are found the compulsory hours for supplying the repairing shops, as also the hours for taking delivery of wagons repaired by these shops.

It is expected that the strict application of the forms by the operating department will reduce the average operating immobilisation to less than 2 days. At present, for wagons repaired in sectional shops, this immobilisation still amounts to 3.6 days.

C. — Immobilisation at the expense of the rolling stock department.

The rapidity with which repairs to wagons are carried out is a question of quantity of labour and above all of organisation of labour.

As the maintenance places in the stations only attend to greasing and the replacing of a few spare parts, wagons usually stop there only half a day, which is the minimum allowed in accordance with the station forms.

In the sectional shops where, according to the whims of the foremen, the work might be considerably more or less, the orders given at present specify that the workshop is to restrict itself strictly to putting the wagons in a fit state for traffic, viz. that a vehicle coming out repaired shall comply with the R. I. V. and give safety as regards load. This is the only condition imposed when the vehicle comes out, except that the work has to be properly done.

It is therefore allowed for the workshop not to do all the work that might be required if the vehicle is to be put into a perfect state of repair, whilst insisting that any work actually done shall be properly done.

It is considered as a general rule that the role of sectional workshops is not to improve the general state of rolling stock — a role which belongs to the central

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DESPATCHING-FORM FOR DAMAGED WAGONS

Montignies-Formation — Station having { a greasing depot. / a maintenance depot

...ass of ...icle.	NATURE OF WORK TO BE DONE.	Wagon to be sent: to the station at	Wagon to be sent: to the workshop or maintenance depot.	No. of the forwarding goods train.	Time of arrival at destination.	Service to be requisitioned.	*Remarks.*
	1. Lifting	Charleroi.	Workshop.	6693/6299	7 a. m.		
	2. By workshop	do.	do.	do.	do.		
	3. Greasing	Montignies.	Maintenance depot.	...	8 a. m.		
H	4. Putting on special track.	do.	do.	...	do.		
	5. Repairs to avoid transshipment	do	do.	...	do.		
	6. Immediate repairs	...	...	...	...	Montignies.	
	1. Lifting	Charleroi.	Workshop.	6693/6299	7 a. m.		
	2. By workshop	do.	do.	do.	do.		
	3. Greasing	Montignies.	Maintenance depot.	...	8 a. m.		
IF	4. Putting on special track.	do.	do.	...	do.		
	5. Repairs to avoid transshipment	do.	do.	...	do.		
	6. Immediate repairs	...	...	...	...	do.	
	1. Lifting	Charleroi.	Workshop.	6693/6299	7 a. m.		
	2. By workshop	do.	do.	do.	do.		
	3. Greasing	Montignies.	Maintenance depot.	...	8 a. m.		
IPV	4. Putting on special track.	do.	do.	...	do.		
	5. Repairs to avoid transshipment	do.	do.	...	do.		
	6. Immediate repairs	...	...	...	...	do.	
	1. Lifting	Charleroi.	Workshop.	6693/6299	7 a. m.		
	2. By workshop.	do.	do.	do.	do.		
	3. Greasing	Montignies.	Maintenance depot.	...	8 a. m.		
PD	4. Putting on special track.	do.	do.	...	do.		
	5. Repairs to avoid transshipment	do.	do.	...	do.		
	6. Immediate repairs	...	...	...	...	do.	
	1. Lifting	Charleroi.	Workshop.	6693/6299	7 a. m.		
	2. By workshop	do.	do.	do.	do.		
ther	3. Greasing	Montignies.	Maintenance depot.	...	8 a. m.		
ecial	4. Putting on special track.	do	do.	...	do.		
agons	5. Repairs to avoid transshipment	do.	do.	...	do.		
	6. Immediate repairs	...	...	...	...	do.	

A. Concentration in the station of damaged rolling-stock :
Track 12 of group IV and 12 of group III.

B. Received by Rolling Stock Service before 8 a. m.

C. Delivery is taken on track 11 of group III.

D. Rolling stock returned repaired at 5 p. m.

E. This rolling-stock is received by Traffic Service on track 11 of group III.

Sundry.

Fig. 6.

workshop — but to enable the wagon to give the maximum of service whilst being used by the traffic department.

On the other hand, as the number of wagons sent to a workshop varies essentially, and the minimum amount of immobilisation being the main point to look after, each workshop should have a certain reserve of labour, to be used for the purpose of generally improving the rolling stock.

It is with this object in view that workshops, with the labour at their disposal, and maintenance work having been attended to, should put into a good state of repair those wagons of which the general state leaves something to be desired.

According to the instructions given, wagons in a good state of repair should have a sound frame; all improvement work on the frame is to be done by the central workshops; those wagons that have a sound frame should have their floor removed and put into a good state of repair or else renewed entirely, the frame should be properly scoured and then painted with two layers of red lead; the wagon should then be completely painted after a thorough repairing of its bodywork and the eventual carrying out of any changes ordered.

It is considered that this repair work will last about 4 years, and the output of the sectional workshops must be regulated accordingly.

At present the average immobilisation of wagons repaired in sectional workshops is 1.8 days; many of the wagons only remain there for 4 hours.

It is evident that rolling stock-immobilisation in central workshops is longer as, apart from taking longer to repair, one must reckon on a longer waiting period at a central workshop before being taken in hand. The programme considered consists in reducing this waiting period to 5 or 6 days and organising the repairs to be done within 12 days, making a total of 18 days in all.

At present, the average is still a month.

As regards the repairs, we insist on their being complete, including a thorough repair of the frame. We intend, in fact, that wagons should do 8 years' work before returning to the central workshops.

In consequence of accidents, certain vehicles will, of course, have to be sent to a central workshop before their time.

In order, therefore, to maintain an average of 8 years, one must repair a certain number of wagons in such a manner that they will last on the average more than 8 years. We reckon that we shall be able to achieve this by doing so called « perfect » repairs, or making practically new those wagons of which the frame is in a new condition after repairs.

Finally, the organisation of labour in the workshops has already been thought out with much care; this has enabled us to reduce to 12 days the repairing of wagons to a perfect condition.

As an instance of organisation, we may mention the lifting of the wagons which is regularly done in 10 minutes.

The principal characteristic of the measures adopted is the systematic efforts towards the preserving of the frame from rust and the bodywork by means of good painting.

With this programme, it is necessary to produce each day a certain number of « 8-year » repairs and « 4-year » conditionings.

The lightening of work in shops consequent on adopting rational methods has been such that, the maintenance work having been properly done, it has been possible to keep pace with the « 8-year » and « 4-year » repairs output.

If the output were considered insufficient at any given moment, we should immediately remedy this by extending the means at our disposal, but it is permissible to consider the present means as being sufficient, taking into account the continual improvement in the plant and output.

But these organisation methods would only give good results it they were permanently and minutely looked after.

CHAPTER V.

Controlling measures.

The immobilising of rolling stock being the most important factor to follow, the extent of it is ascertained daily by the central rolling stock department.

With this object in view, each stopped wagon bearing a *stop*-label must have a document such as is shown in figure 7, drawn up by the official who has made out the rejection-label (station master or his delegate).

This document is immediately sent to the central wagon depot, where it is examined and filed.

On the other hand, each workshop sends daily to the same central office a list of wagons received for repairs, using a form as shown in figure 8.

Finally, all repairing services send daily to the same central office a statement of wagons repaired (see form B, figure 9).

In view of this, the central office can :

1. verify whether stations keep to the despatching rules;

2. see that the rolling stock-immobilisation in workshops is not excessive;

3. ascertain the daily extent of the traffic-immobilisation;

4. ascertain the daily extent of rolling stock-immobilisation and consequently,

5. estimate the amount of total immobilisation.

On the other hand, any wagon sent to an R garage has a document similar to that of the rejected wagon.

Therefore, a permanent stock-list of the R garages is kept at the central office.

Finally, a special classification of documents by repair shops enables the daily immobilisation of all the shops to be ascertained.

The personnel entrusted with this work comprises about ten officials mostly re-educated men, viz. workmen who have met with accidents in their own services and consequently incapable of performing their normal duties.

The various daily statistics are made within 48 hours, i. e. the immobilisation on the 16th at midnight would be known on the 18th at the end of the day.

In order to enable any repairing service to help in the improvement of total-immobilisation, the latter, made up *a priori* for the whole system, has been later divided among all workshops, taking into account their means of action and any circumstances peculiar to them.

The result of this is that immobilisation counted to any shop does not include only wagons on its premises, but also rejected wagons that are intended to go there but are still at stations.

CHAPTER VI.

Part played by the personnel.

These organisation measures, submitted to a minute control by the central service, would have appeared incomplete if they had not been accompanied by reforms that affected the overseeing staff pecuniarily, with a view to the final object we had in mind.

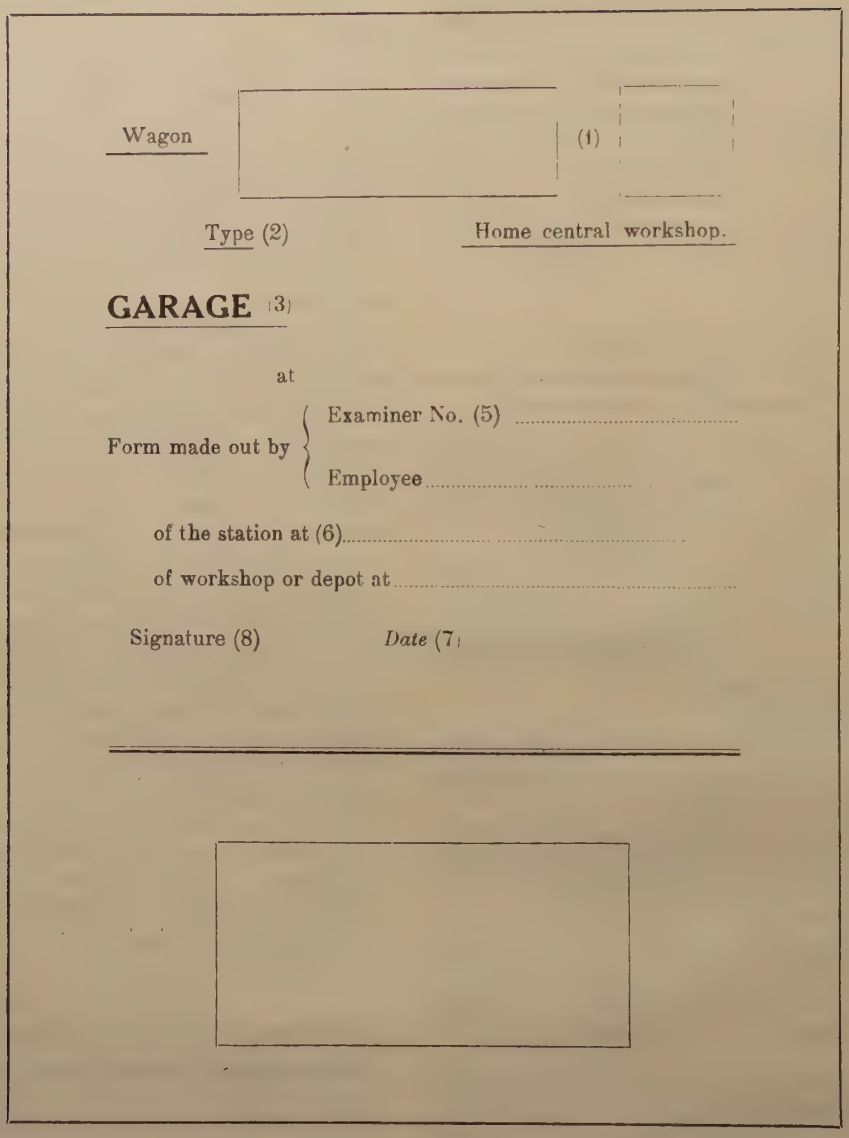


Fig. 7.

The premium system was extended and modified in such a manner that officials were induced to attain a reduction of immobilisation.

The overseeing and managing staff of shops get premiums in a proportionately inverse ratio to the amount of immobilisation in their shop. The result of this

...o. of day .....

Workshop No....

Statement of damaged wagons received.

...o.	Number of wagon.	Type.	Date stopped.	Presumed extent of repairs.			Forwarded by	*Remarks.*
				Frame.	Bodywork.	Total.		
)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Fig. 8.

...No. of day .....

Workshop No......

Maintenance depot

.....

Statement of wagons repaired.

Number ...f the wagon.	Description of the wagon.						Former repairing shop.		Number of days between two repairs.	Immobilisation.		Extent of the repairs in hours allotted.	NATURE of the main damage.	Cause of the damage.
	Type.	Home central workshop.	Year of construction.	Parts.			Number.	Date.		Operating.	Rolling-stock.			
				Body.	Draw and buffing gear.	Wear of tyres.								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Fig. 9.

is that a foreman of a wagon repairing shop has interest not only to see that repairs are effected quickly, but also to see that no truck is rejected unduly — from whence we have a check over the examiners — and also that wagons are sent to him without delay — from whence the shops can control the fact that schedules are being complied with.

The examiners get premiums in a proportional inverse ratio to the immobilisation in their group; it is therefore in their interest to decrease any such immobilisation.

Finally, officials of maintenance depots having premiums based on a similar system find it in their interest to repair as many wagons as possible, so as to reduce the expenses of the neighbouring repair shop.

CHAPTER VII.

Results obtained.

The diagram, figure 4, giving on the one hand the number of wagons rejected and on the other hand the number of wagons immobilised, shows that the results anticipated have been attained and even surpassed.

It may be of use to give below the total hours of labour per day in sectional workshops from the 1 January 1928, in order to show that these results have been obtained in spite of a considerable reduction in the number of hands employed :

	1928	1929
January . . .	16 570	16 577
February . . .	17 545	13 190
March	17 130	14 735
April	17 700	16 375
May	17 550	16 330
June	18 300	16 530
July	20 440	15 593
August	18 970	15 088
September . .	18 615	14 692
October	17 983	—
November. . .	18 920	—
December . .	17 320	—

It goes without saying that serious repairs done according to such a programme are more costly, both as regards labour and materials. The methods in use, however, are of too recent application to give precise criticism on this point. Whatever the result of a comparison between this method and the one used formerly, there is not doubt that finally the cost price of the maintenance of the whole of the rolling stock will continue to decline.

Temporarily, at least, the expenses must be higher because they tend to improve the standard of the stock and to carry out systematically the alterations and improvements acknowledged to be necessary. When these sacrifices have been made, the Company shall be face to face with a normal situation in which it will have to maintain a stock in which the age of the vehicles will be brought down to normal limits.

October 1929.

[621 .132.1 (.42)]

BRITISH LOCOMOTIVES IN 1929.

DESIGNS AND WORK,

By J. F. GAIRNS,
Membe , Institution of Locomotive Engineers,
Member, Institute of Transport,
Editor : « The Railway Magazine » and « The Railway Year Book ».

Figs. 1 to 7, pp. 1672 to 1678.

I. — Designs.

In one respect, 1929 will rank as one of the most remarkable in locomotive history, in that it witnessed the completion of two engines, each representing a notable departure from ordinary practice and constituting two distinctive experiments in the utilisation of steam pressures substantially above anything hitherto used in British locomotive designs. These are, respectively, Mr. H. N. Gresley's compound 4-6-4, with Gresley-Yarrow water-tube boiler and other special features, and designed to work at 450 lb. per square inch, and Sir Henry Fowler's application to a « Royal Scot » class locomotive of the Schmidt double-pressure system, including the use of steam at 1 400 and 900 lb. per square inch, on a system tried in Germany two years ago.

Mr. Gresley's engine is illustrated in figure 1, and, as will be seen, presents a decidedly unconventional appearance. Particular interest attaches to the boiler. As it was proposed to use a pressure of 450 lb. per square inch, a boiler of the water-tube type was decided upon. This has been designed by Mr. Gresley in conjunction with Mr. H. E. Yarrow specially to meet the requirements of locomotive service, and has been constructed by Yarrow & Co., Ltd., of Glasgow. It is built up with one steam drum 3 feet inside diameter by 27 ft. 11 5/8 in. long, and two water drums on either side of the firebox, each 18 inches in diameter and 11 ft. 5/8 in. long, and two other drums under the forward part of the boiler, each 19 inches in diameter and 13 ft. 5 3/4 in. long. The forward drums are connected to the steam drum by 444 two-inch tubes and 74 2 1/2-inch tubes. The drums at the side of the fire grate are connected to the steam drum by 238 2 1/2-inch tubes, and there is a back screen of 12 2 1/2-inch tubes. All the drums are solid forged and machined all over. The use of a pressure of 450 lb. necessitated a complete change in all the

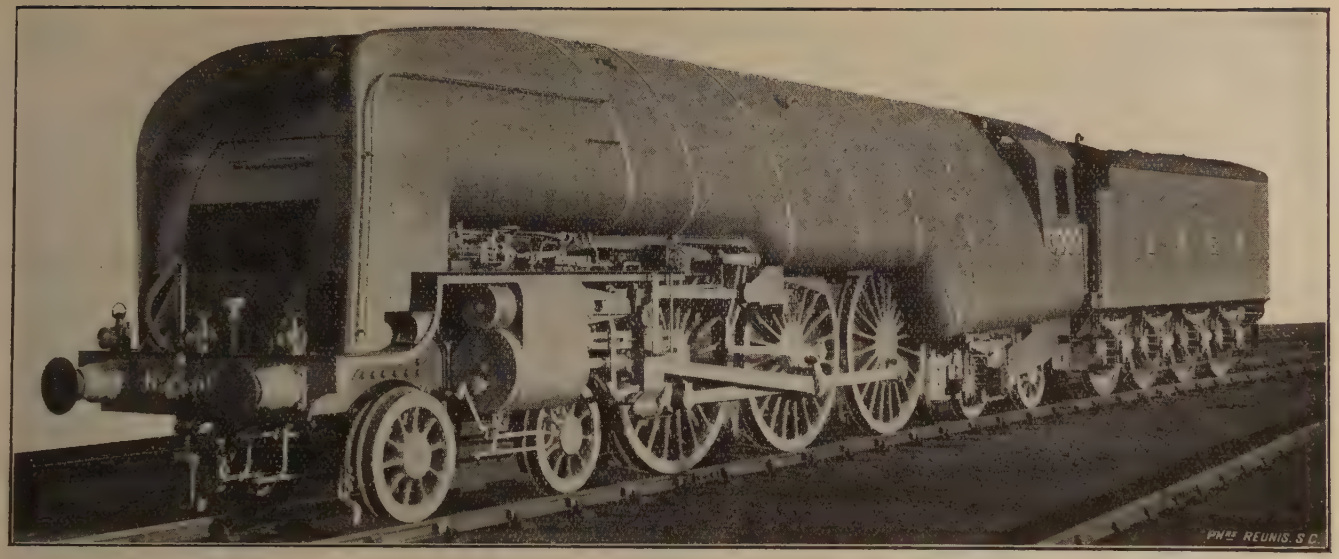


Fig. 1. — 4-6-4 high pressure compound water-tube boiler locomotive, London & North Eastern Railway.

Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

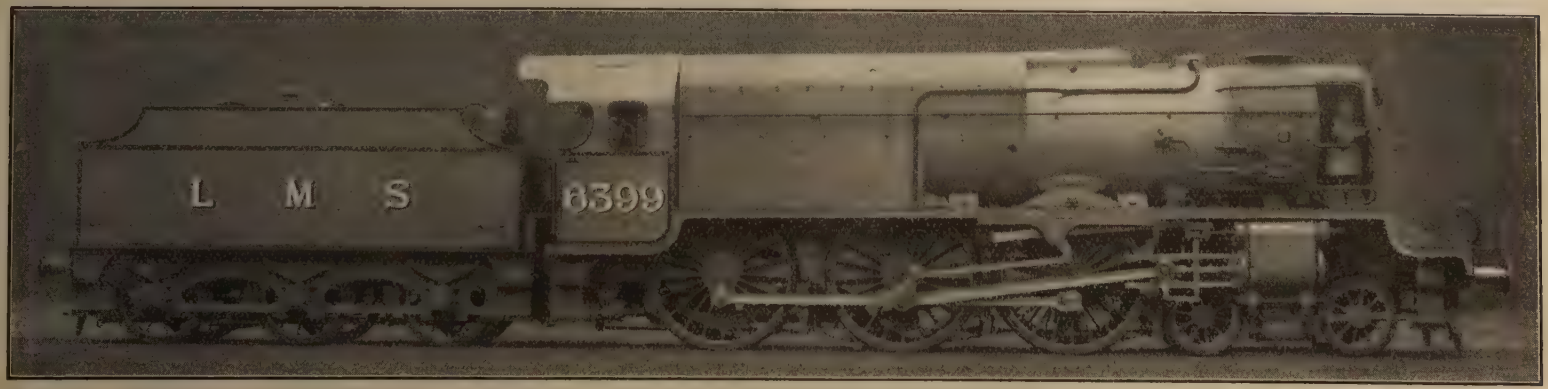


Fig. 2. — Three-cylinder compound double pressure locomotive, London Midland & Scottish, Railway.

Sir Henry Fowler, K. B. E., Chief Mechanical Engineer.

ordinary boiler practices, and special forms of safety valves, regulator, water-gauge and injectors have had to be provided. The main regulator admits high-pressure steam to the high-pressure steam chests. To facilitate starting, an additional supply of steam can be admitted through a small regulator to the low-pressure steam chest, but this must be closed directly the engine has got away. A special form of superheater, supplied by the Superheater Company, has been fitted in the main flue on the boiler side of the regulator, so that the elements are always under full steam pressure. The elements are connected to two forward headers located immediately in front of the water tubes. The front end of the engine is of novel design, as the boiler is built to the extreme limit of the gauge. Therefore, it is not possible to have a chimney of the ordinary pattern projecting above the top line of the boiler. Before arriving at the shape of the front end, Mr. Gresley carried out experiments, in conjunction with Prof. Dalby, at the City and Guilds Technical College.

The engine is a four-cylinder compound, having two high-pressure cylinders, each 12 inches in diameter and 26 inches stroke, driving on the front coupled axle. The low-pressure cylinders are situated outside the frames and are standard with the cylinders used on the *Pacific* engines, being 20 inches in diameter by 26 inches stroke. Two sets of valve gear are employed for operating the four valves. Walschaerts valve gear is fitted to the outside cylinders and the valves of the inside high-pressure cylinders are operated by means of a novel rocking shaft arrangement patented by Mr. Gresley. There are two sets of steam reversing gear, one to control the Walschaerts valve gear and the other to control and vary the cut-off of the high-pressure cylinders. The trailing end of the engine is carried on two axles, the forward one being similar to that in the *Pacific* engines, having Cartazzi axle-boxes, and the rear one fitted to a Bissel truck with the centre located immediately under the front of the firebox. It was not possible to fit a bogie to the trailing end. The engine is fitted with a corridor tender of the standard type as used on the company's *Pacific* engines.

Sir Henry Fowler's engine (fig. 2) is not quite so unconventional in general appearance, but it is equally remarkable in regard to design and operating system. The engine was built in conjunction with The Superheater Co. Ltd. at the works of the North British Locomotive Co. Ltd. The design of this locomotive follows the « Royal Scot » class with regard to the frame, but the engine is a three-cylinder compound, the high pressure cylinder being situated between the frames and the two low pressure cylinders outside the frames. The boiler provided is of the Schmidt high pressure type, and consists of three distinct systems of boilers, each carrying a different pressure. The system having the highest pressure, 1 400-1 800 lb. per square inch, the variation in pressure depending on the rate of firing is in the form of a « closed circuit », consisting of a number of pipes which form the sides, roof and back end of the firebox. These pipes are connected at the bottom to a foundation ring and at the top to equalising drums. From the equalising drums, pipes are led to evaporating elements which are situated in the high pressure drum.

This closed circuit is initially filled to a predetermined level with pure water, and this latter is the medium by means of which heat is transmitted from the firebox to the evaporating elements in

Fig. 3. — 0-8-0 goods and mineral locomotive, London Midland & Scottish Railway.

Sir Henry Fowler, K. B. E., Chief Mechanical Engineer.

Fig. 4. — Three-cylinder 4-4-0 locomotive with rotary cam valve gear, London & North Eastern Railway.

Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer.

the high pressure drum, which furnishes steam at 900 lb. per square inch for the high pressure cylinder of the locomotive. This drum is of nickel steel, but is not in contact in any way with the fire. It is fed by water drawn as required from the low pressure boiler by means of a pump. The low pressure boiler occupies the same position as the barrel of the normal locomotive boiler, and the water is evaporated by the gases passing through the boiler tubes. The barrel of this low pressure boiler is also of nickel steel, but both tube plates are of mild steel. An ordinary live steam injector is provided on the driver's side, and an exhaust steam injector on the fireman's side of the engine to feed the low pressure boiler. As steam is raised much more quickly in the high pressure drum than in the low pressure boiler, arrangements are made to bye-pass, by means of an intercepting valve, any excess steam from the high pressure drum into the low pressure boiler, thus avoiding waste through blowing-off.

The method of working is more or less normal. The regulator handle works both the high pressure and the low pressure regulator simultaneously. On opening the regulator, steam is admitted into the high pressure cylinder after passing through the high pressure superheater situated in the lower boiler tubes. Exhausting from the high pressure cylinder, the steam enters a mixing chamber, where it is met by low pressure steam at 250 lb. pressure, which has previously passed through a low pressure superheater situated in the upper boiler tubes. From the mixing chamber, steam enters the two outside cylinders.

As both engines will be undergoing their principal trials and tests in actual service in 1930, it may be anticipated that there will be interesting material for consideration in due course, while the practically simultaneous testing of two distinct applications of high steam pressure should add much to locomotive engineering knowledge and experience.

Apart from these engines, there are no very notable new designs to the credit of 1929, but three new classes call for brief notice. On the London Midland and Scottish Railway, Sir Henry Fowler placed in service a new class of 0-8-0 heavy goods and mineral engines. These were constructed at Crewe, and the design is based to some extent upon the latest 0-8-0 engines of the late London & North Western Railway. They have, however, a later type of boiler, Walschaerts valve gear with long travel valves instead of Joy gear with short travel valves, and features associated with present London Midland & Scottish practice.

Sir Henry Fowler has also introduced a small 0-6-0 short wheelbase tank engine for shunting in docks and yards where a bigger engine cannot be used because of curves and other restrictions. The diameter of the wheels is 3 ft. 11 in., and the total fixed wheel-base only 9 ft. 6 in. This short wheelbase, together with the provision of Cartazzi type trailing axleboxes and ball-jointed coupling rods, will enable the engines to negotiate curves of as small as 2 1/2 chains (165 feet) radius. The engines are fitted with outside cylinders driving the middle pair of wheels, Walschaerts gearing being used for actuating slide valves operating above the cylinders. It has been possible to embody a standard type of boiler working at 160 lb. per square inch, and all standard fittings, such as Ross « pop » safety valves, water gauges, etc., have been used. Although the engines are of a small type, a high tractive effort, namely, 18 400 lb.,

has been provided in order to deal with the heavy work at the docks.

Otherwise, there is nothing very special to record in regard to the London Midland & Scottish Railway, except that the standard classes have been added to and are, to some extent, replacing pre-grouping engines on various sections. There has also been a good deal of rebuilding and reboilering of older engines, in which connection the progressive system adopted at Crewe, and a corresponding system since adopted at Derby and to be applied to other large repair depots, have enabled a systematic policy of rebuilding to be carried out on sound and efficient lines.

On the London & North Eastern Railway there are no further new designs to be described, but additions have been made to standard classes, and two of the 4-4-0 three-cylinder express passenger locomotives (fig. 4), have been fitted with a rotary cam poppet valve gear supplied by the firm of Lentz Patents, Limited. The arrangement adopted is the « R. C. » (rotary cam) poppet valve gear, and consists of a camshaft which obtains a rotary motion by means of suitable gears and shafting so arranged that the rotation of the camshaft can be synchronised with that of one of the coupled axles. The camshaft is placed horizontally above the cylinders, with its axis at right angles to the centre line of the locomotive. The steam inlet cams for each cylinder are made in two separate sections; those for forward-gear running provide for five different rates of admission, ranging from a minimum cut-off of 15 % to a maximum of 75 % in full gear, whilst for back-gear running a further set of cams is used which gives two rates of admission: one for full gear and the other giving a shorter rate of cut-off at 35 %. In addition, there is provided a cylindrical cam for each cylinder for the purpose of closing the steam valves when the engine is placed in mid-gear, in which position the exhaust valves are held open by a similar cam of larger diameter in the exhaust set. The arrangement of the exhaust cams is somewhat similar, but only three different profiles are provided. Separate exhaust cams enable the point of release to be adjusted to suit the cut-off, and in this instance release takes place at 90 % in full gear and 80 % for all other cut-offs. The arrangement of the valves is similar to that employed with the oscillating cam type of gear which utilises a link motion.

Further, Mr. Gresley has reboilered one of Sir Vincent Raven's 4-6-2 engines, built by the late North Eastern Railway immediately prior to grouping, with a Gresley type boiler, as shown in figure 5. This means altered boiler and certain other dimensions, and it will be interesting to note how the engine thus reboilered compares, in actual service, with others which have not been so dealt with.

On the Great Western Railway, Mr. C. B. Collett has not introduced any new designs, but has added to the useful « Hall » class of 4-6-0's described last year, has rebuilt more of the earlier four-cylinder 4-6-0 express engines of the « Castle » class, and has placed in service further 0-6-2 and 0-6-0 tank engines, either built at Swindon or by outside firms.

On the Southern Railway, Mr. R. E. L. Maunsell has introduced, for the first time on that line, a 0-8-0 tank engine (fig. 6) for heavy shunting, particularly in hump yards. They have three cylinders, one driving the second axle and the others the third axle; ordinary Wal-

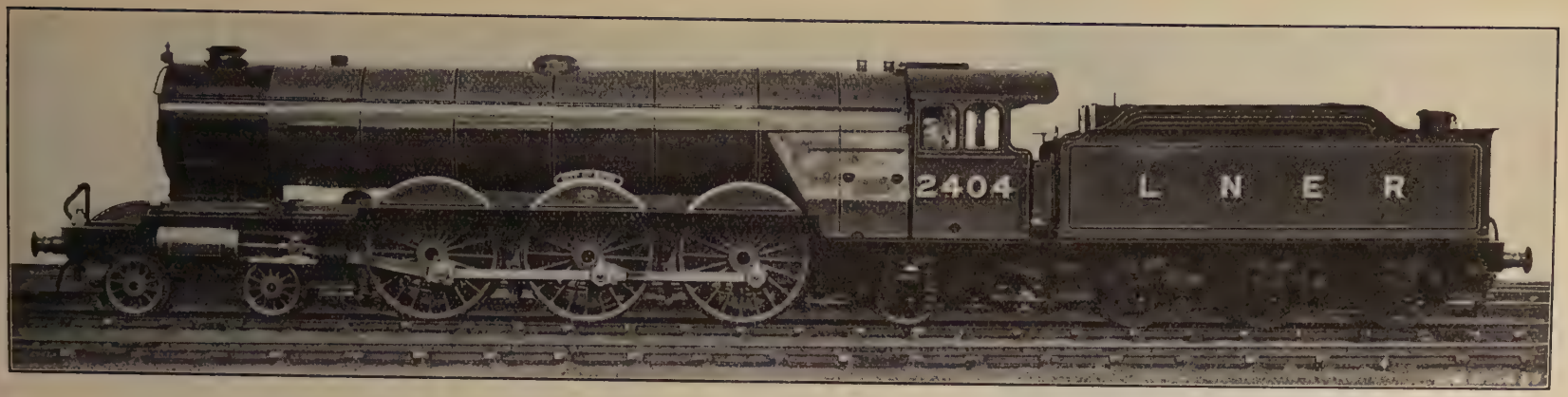


Fig. 5. — Raven three-cylinder 4-6-2 locomotive fitted with Gresley boiler, London & North Eastern Railway.

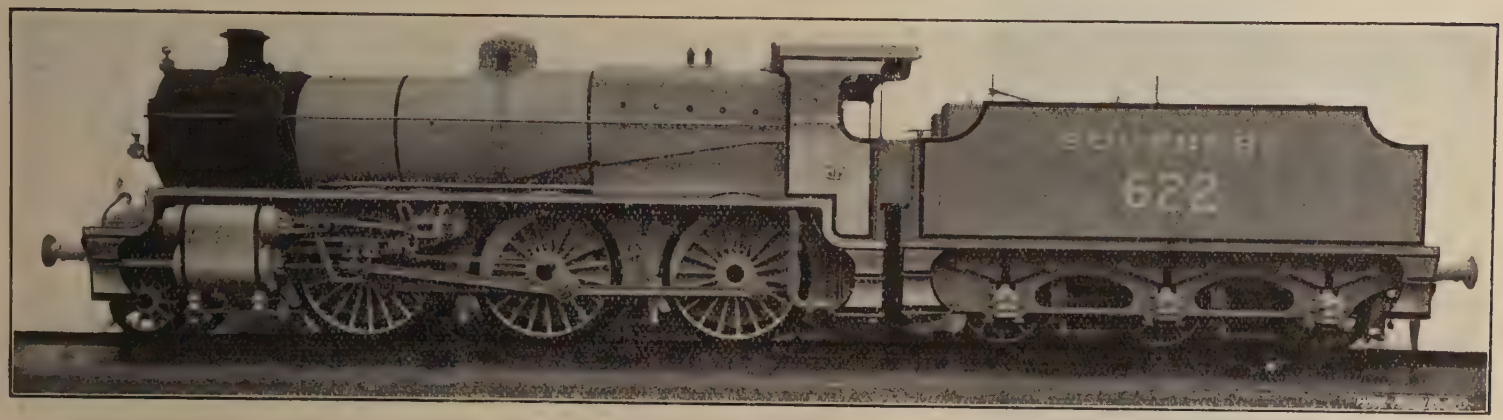


Fig. 7. — 2-6-0 main line locomotive, Southern Railway.

Mr. R. E. L. Maunsell, C. B. E., Chief Mechanical Engineer.

Fig. 6. — Three-cylinder 0-8-0 shunting tank locomotive, Southern Railway.

Mr. R. E. L. Maunsell, C. B. E., Chief Mechanical Engineer.

schaerts valve gear for the outside cylinders and a modified form of that gear for the inside cylinders; steam reversing and other features. Mr. Maunsell has also built a number of 2-6-0 engines (fig. 7) constituting a development of the earlier engines of this class, and these are proving very useful on widely-varied duties. They are, in fact, definitely allocated to passenger service, for which their 6-foot (instead of 5 ft.-6 in.) coupled wheels render them distinctly suitable, and in practice they have to a certain extent taken the place of 4-4-0 engines, with the consequent ability to work heavier trains and, at the same time, attain the highest speeds called for by ordinary main line schedules. Further four-cylinder 4-6-0's of the « Lord Nelson » class have been placed in service, and one of these has a slightly longer boiler and a few detail modifications.

In Ireland, Mr. G. T. Glover has rebuilt a number of 4-4-0 and 0-6-0 engines used on the Great Northern Railway, while Mr. W. H. Morton, who has succeeded Mr. J. R. Bazin as Chief Mechanical Engineer of the Great Southern Railways, has similarly dealt with various designs in use on that system.

II. — Work.

Although there were few notable developments in train schedules, there were some of an exceptional character. The most sensational was the acceleration, by the Great Western Railway, of the 3.45 p. m. up train from Swindon to cover the 77.3 miles to Paddington in 70 minutes (75 minutes was made the schedule in 1927), thus introducing for the first time an average booking speed of no less thans 66.3 m. p. h. On the London and North Eastern Railway, the acceleration of the 4.55 p. m. from Marylebone enabled Leicester to be reached in 108 minutes (103 miles). On the Southern Railway two-hour trains between London and Bournemouth were reinstated for the first time since the war in the form of « Bour-

nemouth Limited » expresses. Other items of interest are the working of a « Torquay Pullman » express by the Great Western Railway non-stop between Paddington and Newton Abbot (193.9 miles), and the running of a night London Midland & Scottish sleeping car express from Crewe to Carstairs (214.5 miles). There were, of course, a number of alterations of train schedules, a degree of speeding up, the introduction of Pullman restaurant cars on various trains, and other developments indicating progress and improvement, but not calling for detailed reference here. Practically all the notable developments of 1928 were, however, retained, including the London-Edinburgh (392.7 miles) and London-York (188.2 miles) runs of the London and North Eastern Railway, the London-Carlisle (298.2 or 301 miles) and the Glasgow-Crewe (243.3 miles) runs of the London Midland & Scottish Railway; the Paddington-Plymouth (225.7 miles) and Paddington-Torquay (199.7 miles) runs of the Great Western Railway, with others not much under 200 miles, and such of these as come within the experience of the writer may first receive attention.

Both the London & North Eastern London-Edinburgh and London Midland Scottish London-Carlisle runs are operated more to provide uninterrupted runs for through passengers than to reduce journey times so that, although they constitute notable achievements, they do not involve high-speed running to such a degree as in the case of certain other trains. Both routes include steeply graded sections, and at places reduced speed is entailed, so that the working of these trains calls for a high order of performance and constitute severe tests of reliability, especially as the loads are by no means light, while speeds could be materially improved upon were there need therefor.

On the London-Edinburgh run of the London and North Eastern Railway, No. 2563, *William Whitelaw*, named after the Chairman of the Company, running with a corridor tender to enable enginemen to be relieved while travelling about halfway, had a load of about 380 tons. The generally rising and hard 12.7 miles to Potters Bar were covered easily in 21.5 minutes, and the next 63.7 miles to Peterborough (reduced speed) in 63.7 minutes (a curious equality of time and distance), Stoke summit being passed 30.1 minutes later (25.7 miles mainly rising). The 55.9 miles to Doncaster took 62.2 minutes, and the 28 miles to York (reduced speed at Selby and through York) took 40.9 minutes. The York-Newcastle stage was covered very easily in 104.6 minutes (80.6 miles), and after passing slowly through Newcastle the fairly difficult stage of 66.9 miles to Berwick took 87 minutes. The remaining 57.5 miles to Edinburgh, including the climb to Grantshouse summit, were run in 75 minutes, thus completing the run of 392.7 miles, without stop, in 8 hours 5 minutes, exactly as booked.

Whereas last year the « Royal Scot » non-stop run of the London Midland & Scottish Railway was described in the up direction and on the Sunday schedule, it can now be considered on a weekday basis, and in the down direction. This means that the non-stop run is of 301 miles, as engines are changed at Kingmoor engine sheds about a mile beyond Carlisle station, instead of at the London and North Western engine sheds south of Carlisle as in the case of the up non-stops. « Royal Scot » class three-cylinder 4-6-0 No. 6139, *Ajax*, had the standard

load of nine bogie coaches for Glasgow and six for Edinburgh, a weight of about 430 tons behind the tender. Matters were taken rather easily for a time, though Tring (31.7 miles mainly ascending) was passed in 40.6 minutes. Thence downhill to Bletchley the 15 miles were run in 13.4 minutes, and the next 35.9 miles to Rugby (reduced speed) took 36 minutes. The comparatively straightforward 51 miles to Stafford occupied 51.9 minutes, and Crewe (158.1 miles) was passed in 170.2 minutes from London. Thence to Preston the 50.9 miles occupied 64 minutes, and the 27.3 miles to Carnforth 29.3 minutes. The hard 19.9 miles thence to Grayrigg occupied 28.2 minutes. Then comes a short easy stretch of 6 miles (6.5 minutes), of which full advantage was taken, as Tebay is almost the beginning of the great Shap incline, 4 miles at 1 in 75. The ascent was made very steadily, the summit being passed in 9.4 minutes (5.5 miles). An easy run down, with steadying brake applications and a slow run through Carlisle station, brought us to Kingmoor sheds in 35.6 minutes from Shap summit (33.3 miles). The complete run from London had thus been made, very steadily and without undue effort, in 343.1 minutes (301 miles).

A similar engine, No. 6132, *Phoenix*, took on the train, passing Beattock in 44.4 minutes (39.7 miles), climbing unaided the 10 miles, mainly at 1 in 75, to the summit in 23 minutes, and completing the non-stop run from Kingmoor (Carlisle) to Symington, 64.9 miles, in 86 minutes. Here the train was divided and No. 6132 took on the Glasgow portion to Glasgow in 48 minutes (35.4 miles), though this part of the route is not suited to real high speed work.

On the Great Western Railway « Cornish Riviera » express, with a train of the new stock placed in service last summer on this run, the writer had his first experience of a late arrival, but, as will be seen, this was more than accounted for by the unusual delays experienced near Exeter, too late in the journey to permit of recovery. The load was the full one for summer working of 11 coaches (328 tons empty or 360 tons loaded), with an additional 71 tons (74 tons loaded) as far as Westbury (95.6 miles), where two vehicles were slipped. With 464 tons, four-cylinder 4-6-0 (250-lb. pressure), No. 6004 *King Georges III*, passed Reading in 35.4 minutes (36 miles) and covered the next 34.1 miles to Savernake (mainly rising grades) in 36.5 minutes. Thence to Westbury the 24.5 miles occupied 23.5 minutes, so that the first 95.6 miles had been run in barely the 94 minutes allowed, and that with the full load. The next 47.3 miles to Taunton occupied 49.35 minutes, with one check, and the 30.8 miles to a very bad check outside Exeter, by which a stop was only just avoided, took 31.4 minutes, notwithstanding that this section includes the stiff climb up to Whitehall tunnel. However, Exeter (St. Davids) was passed in 176.6 minutes from London (173.7 miles). The 20.2 miles to Newton Abbot took 23.7 minutes (curves necessitate medium speed on parts of this section), and then the very hard 31.8 miles to Plymouth, with their grades of 1 in 42, 47, 52, etc., were completed in exactly the 45 minutes allowed. This meant that almost 5 minutes were lost on scheduled time, but with delays that fully compensated therefor.

These are the three chief British journeys of extreme non-stop length (with their up equivalents), but a few notes

must now be given of shorter runs of a notable character. On the 66.3 m. p. h. Swindon-Paddington run, No. 4074, *Caldicot Castle*, with a load of 250 tons, was delayed approaching Didcot, so that the 24.2 miles took 24.3 minutes. Thence to Reading the 17.1 miles were run in only 14.9 minutes, and the following 17.5 miles to Slough in 16.1 minutes. Here, however, there was another check, so that the final 18.5 miles, with an easy run into the terminus, took 18.6 minutes, and the complete run of 77.3 miles had thus taken 74.2 minutes instead of the 70 minutes allowed. The two severe checks, both in the middle of high speed stages, must however, be regarded as affording sufficient justification for this loss of time, especially as when the inaugural run was made it took 68 minutes, a time which has been reached also on other occasions, with many further punctual runs with the same and similar engines.

The principal Southern Railway novelty this year was the re-introduction of a 120-minute booking between London and Bournemouth. On a very stormy evening, No. 789, *Sir Guy* (« King Arthur » class 4-6-0), with 330 tons, passed Woking (24.5 miles), (permanent way slack intermediately) in 30.2 minutes, took 23.2 minutes for the next 23.5 miles to Basingstoke, passed Winchester (66.7 miles) in 70.9 minutes from London, including 10 miles of fairly hard climbing, and was through Southampton West (slacks for curves) in 85 minutes (79.5 miles). Thence to Christchurch the 25 miles took 28.9 minutes, but relaying slacks onwards to Bournemouth rendered the completion of the 108 miles run from London being delayed, so that 122 minutes were taken against the 120 allowed, a highly creditable performance, especially in view of the high wind and stormy conditions prevailing.

A few other runs may be briefly summarised. On the London North Eastern Railway, No. 2568, *Sceptre*, with 380 tons, passed Berwick (57.5 miles) in 66.6 minutes from Edinburgh and covered the 66.9 miles thence to Newcastle in 77.6 minutes. On another turn, No. 4472, *Flying Scotsman*, with 370 tons, covered the 80.6 miles from Newcastle to York in 97 minutes, with incidental delays. On still another occasion, No. 2747, *Coronach*, with 410 tons, ran from Doncaster to Grantham (50.5 miles) in 58 minutes, start to stop. The 29.1 miles thence to Peterborough occupied 31.6 minutes. No. 2846, *Donovan*, completed the journey to London in 83.6 minutes (76.4 miles).

With 280 tons, No. 6015, *King Richard III*, on the Great Western Railway, ran from Taunton to London, 142.9 miles in 149.7 minutes. An older 4-6-0 engine, with 370 tons, passed Didcot (53.1 miles) in 55.6 minutes, and after slipping 3 vehicles passed Bath at reduced speed (53.8 miles) 55 minutes later. Two further vehicles were then slipped and Bristol was reached in 124 minutes (118.3 miles). A return journey was complicated by two intermediate stops, not normally allowed for. Nevertheless, the 100 miles from Badminton to London were run in 97.6 minutes, including a stop at Reading instead of slipping, and with slight delays otherwise. The engine was No. 4026, *British Monarch*, and the load about 350 tons.

On the Southern Railway, 4-6-0 No. 780, *Sir Persant*, made the run of 79.5 miles from Southampton West to London in 96.2 minutes, with two checks, and on a fairly easy schedule. On a West of England express, No. 779, *Sir Colgre-*

vance, with 300 tons, passed Basingstoke (47.9 miles) in 56.9 minutes, and took 33.5 minutes for the 35.9 miles to a stop outside Salisbury. An older 4-6-0, No. 746, took the train on from Salisbury, and passed Templecombe (28.8 miles) in 33 minutes, ran thence to Axminster (32.4 miles) in 32.6 minutes, climbed at a good steady speed to Honiton tunnel (practically 10 miles at about 1 in 70), and reached Exeter (Queen Street) in 96.5 minutes from Salisbury (88 miles). On a return working, No. 827, a 4-6-0 mixed-traffic engine, with 360 tons, ran from Exeter to Yeovil Junction (48.7 miles) in 62 minutes, although the route is a hard one.

LEADING DIMENSIONS OF LOCOMOTIVES ILLUSTRATED AND DESCRIBED.

A = Water-tube boiler of special type. — B = Double pressure boiler of special type. — T = Tank engine. — R = Rebuilt.

Figure.	RAILWAY.	Type.	Cylinders. Diameter and stroke (inches).	Diameter of coupled wheels.	Heating surface (square feet).			Grate area (square feet).	Steam pressure (lb. per square inch.)	Weight (engine only) in working order (tons).
					Tubes.	Fire box.	Superheater.			
1	London & North Eastern. .	4-6-4	12 (2) / 20 (2) × 26	6 ft. 8 in.	A	A	A	A	450	103 3/4
2	London Midland & Scottish.	4-6-0	11½ (1) / 18 (2) × 26	6 ft. 9 in.	B	B	B	B	900 / 250	85 1/4
3	— — —	0-8-0	19 × 26	4 ft. 8½ in.	1 434	149.8	352.5	23.6	200	60 3/4
—	— — —	0-6-0 T	17 × 22	3 ft. 11 in.	923	85	—	14.5	160	43 3/4
4	London & North Eastern. .	4-4-0	17 × 26 (3)	6 ft. 8 in.	1 222.28	171.5	246.1	26	180	66
5	— — — . .	4-6-2 R	19 × 26 (3)	6 ft. 8 in.	2 715	215	525	41.25	180	98
6	Southern.	0-8-0 T	16 × 28 (3)	4 ft. 8 in.	1 173	106	—	18.4	180	71 1/2
—	—	2-6-0	19 × 28	6 feet.	1 390.6	135	285	25	200	62 1/4

[621. 132.8]

SUPPLEMENT TO REPORT No 4 (1)

(America)

ON THE QUESTION OF LOCOMOTIVES OF NEW TYPES. IN PARTICULAR TURBINE LOCOMOTIVES AND INTERNAL COMBUSTION MOTOR LOCOMOTIVES (SUBJECT V FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (2).

By A. LIPETZ,

Consulting Engineer, American Locomotive Company, Schenectady, N. Y., Non-Resident Professor, Perdue University, Lafayette, Indiana.

Figs. 22 to 28, pp. 1687 to 1698.

II. — Turbine locomotives.

There is only one turbine-driven locomotive in the Western Hemisphere — a narrow-gauge locomotive of the « Ljungström » system on the State Railways of Argentine for mixed passenger and freight service. The locomotive was built by Nydquist & Holm A. B., of Trollhattan, Sweden, and delivered in Argentine at the end of 1925. Since February 1926, the locomotive has been in service on the Argentine State Railways.

A detailed questionnaire containing 93 questions was sent in February 1929 to the Administration of the Railroad in Buenos Ayres, but only a printed description of the locomotive without any operating data was received in reply to the inquiry. Further correspondence revealed that operating statistics of the turbine locomotive were lacking, that the locomotive was in the repair shops awaiting spare parts from Sweden and that it was not expected that any information about the performance of the locomotive would become available during the year of 1929.

The Chief Mechanical Engineer stated, though, that the most interesting thing that had been already found out from tests made with the turbine locomotive is that condensation of steam can be successfully obtained by the action of an air-cooled condenser on a locomotive (and that, further, in view of the scarcity of water and its quality on various parts of the Argentine road, the economy in water and other advantages which condensation offers for the preservation of the locomotive boiler is what interests the railroad most, more than the economy in fuel. It was also added that as there was only one locomotive of this type on the road, it had been very difficult to establish for it a service that would effectively demonstrate the advantages of this type, as the case would have been if the railroad had a number of locomotives for a complete service.

It is not thought necessary to give here

(1) See *Bulletin of the Railway Congress*, March 1930 number, p. 863.

(2) This question runs as follows : « Locomotives of new types; in particular, turbine locomotives and internal combustion motor locomotives. Construction, efficiency, use and repair. »

a description of the locomotive, which was very elaborately described in the technical press (1). The most complete description can be found in a pamphlet published by the State Railways of Argentine, Mechanical Department, entitled : « Informe Definitivo Sobre Ensayos de Una Locomotora Especial a Turbina y Condensador Sistema Ljungström », Buenos Ayres, 1928. The pamphlet also contains a number of illustrations, diagrams, dynamometer charts, test results, inspection data, and other interesting information.

Like all Ljungström turbine-locomotives, the Argentine locomotive consists of two units: the first carries the boiler and the principal auxiliaries, and has a four-wheel truck in front and six supporting wheels in the rear part of the frame; the second unit carries the main turbine and the condenser, and has eight driving wheels and a two-wheel truck in the rear. The boiler is of the conventional design, has a radial stay firebox, short fire tubes, is equipped for oil firing, has a superheater in the small fire tubes and a rotary air preheater of the Ljungström type which is placed in front of the smokebox. The main turbine has a rating of 1 750 H. P. at 10 000 r. p. m. and is connected with the first pair of driving wheels through a triple reduction gear and a flexible coupling. Other wheels are driven from the first pair by means of coupling rods. The principal part is the condenser; it is of the known air-cooled Ljungström type, consisting of a multitude of flattened tubes between which air is drawn by four powerful fans. The exhaust steam from the main turbine and some auxiliaries is condensed in the tubes and the condensate is used for feeding the boiler. The principal dimensions of the locomotive are as follows :

Road gauge	1.00 m. (3 ft. 3 3/8 in.).
Total length	21.33 m. (69 ft. 11 3/4 in.).
Total wheelbase	16.68 m. (54 ft. 8-5/8 in.).
Rigid wheelbase	4.80 m. (15 ft. 9 in.).
Steam pressure	20 kgr./cm² (284.5 lb. per sq. inch).
Firebox heating surface	12.00 m² (129.17 sq. ft.).
Number of tubes	268.
Length of tubes	2.30 m. (7 ft. 6-5/8 in.).
Outside diameter of tubes	50.8 mm. (2 in.).
Heating surface of tubes	88.3 m² (950.45 sq. ft.).
Total heating surface	100.3 m² (1 079.65 sq. ft.).
Superheater surface	57.0 m² (613.54 sq. ft.).
Air preheater surface	800 m² (8 611 sq. ft.).
Condenser cooling surface	1 200 m² (12 917 sq. ft.).
Diameter of drivers	1.53 m. (5 ft. 1/4 in.).
Tractive effort	15 000 kgr. (33 060 lb.).
Weight on drivers	52 200 kgr. (115 000 lb.).
Weight of locomotive in working order	122 500 kgr. (270.000 lb.).

(1) See, for instance, *The Engineer*, 12 April 1929, p. 398.

Between 23 March and 25 November 1926, four official locomotive runs were made with a dynamometer car from Tucuman, Las Cejas, Pacara and Santa Fe, each run over a distance of approximately 735 to 793 km. (456 to 492 miles). The above cited pamphlet issued by the Argentine State Railways gives results of the official tests (1) which are as follows :

Trip.	1	2	3	4	Average.
Distance, km. (miles)	793 (492)	735 (456)	776 (482)	777 (483)	...
Total work at drawbar, H. P.-hours	4 953	4 108	7 545	6 353	...
Running time, hours	23.30	21.25	22.30	22.12	...
Average output at drawbar, H. P.	213	193	335	286	258
Consumption of water, litres (Br. gallons).	6 100 (1 343)	7 900 (1 739)	8 700 (1 915)	11 500 (2 531)	...
Consumption of oil, litres (Br. gallons).	7 700 (1 695)	8 750 (1 926)	10 800 (2 377)	11 400 (2 509)	...
Water per drawbar H. P.-hour, litres (Br. gallons).	1.23 (0.27)	1.93 (0.42)	1.17 (0.26)	1.81 (0.40)	1.49 (0.33)
Oil per drawbar H. P.-hour, litres (Br. gallons).	1.56 (0.34)	2.13 (0.47)	1.43 (0.31)	1.79 (0.39)	1.68 (0.37)

While the consumption of water is extremely low, amounting to only a particle of what it would be in an ordinary locomotive, the fuel consumption is rather high. Assuming a specific gravity of 0.88 for boiler fuel, the weight of the average oil consumption (1.68 litres) corresponds to 1.48 kgr. of oil per one metric drawbar horse power-hour (or 3.30 lb. of oil per one Br. drawbar horse power-hour). The high oil consumption can be explained probably by the low load factor which resulted in an average output of only 258 H. P., while the locomotive is capable of developing at least 1 500 H. P. at the drawbar.

Data of dynamometer tests with ordinary locomotives on the same districts, with which the above figures could be compared, are not given in the pamphlet, nor were they communicated to the reporter. Neither are there any statistical data available on fuel consumption. There is, however, one intimation in the pamphlet as to the possible economy in fuel of the turbine locomotive : in a chapter entitled « Economic Study » it is assumed for the calculations of savings due to the use of turbine locomotives that the fuel consumption per 1 000 metric ton-kilometres is 10 kgr. of oil for the turbine locomotive and 17 kgr. of oil for the ordinary piston type locomotive (2); this corresponds to a saving of 41 %. It is not indicated whether these figures have been obtained from actual service, or whether they are given as an illustration for calculation.

On page 72 of the above mentioned pamphlet is given a list of major repairs during the year 1926. It appears from the list that during a period of 363 days (from 18 February 1926 to 14 February 1927), the turbine locomotive had been sent to the shops 8 times for repairs

(1) Pp. 73-75 of the pamphlet.
(2) P. 76.

lasting from 5 to 50 days and amounting to a total of 153 days. Thus the locomotive was out of service 33 % of the total time of that period.

As stated at the beginning, the locomotive did practically no work in 1929. No information reached the reporter as to the condition of the locomotive in 1927 and 1928.

CONCLUSION.

In view of the inadequacy of information on the performance of the turbine driven-locomotive of the Argentine State Railways, which is the only turbine locomotive in the two Americas, it is impossible to draw any conclusion regarding the usefulness of locomotives of this type.

III. — Locomotives with water-tube fireboxes.

At the end of 1929 there were only ten locomotives with water-tube fireboxes in the United States and, as far the reporter could ascertain, no fireboxes of this type were in use on locomotives in any other country of North or South America. The boilers of all the ten locomotives had the conventional fire-tube cylindrical shell, the water-tube part taking the place of the Stephensonian radial stay firebox. Two locomotives were on the New York-New Haven Railroad, one at the Baldwin Locomotive Works, five on the Baltimore & Ohio Railroad, and two on the Delaware & Hudson.

The first three groups have fireboxes very similar to the well-known Brotan type, differing in each case, however, in very essential details. The closest to the Brotan firebox is that on the experimental locomotive No. 60 000 of the Baldwin Locomotive Works. The New York, New Haven locomotives have the McClellon boiler, while the Baltimore & Ohio engines are equipped with fireboxes designed by George H. Emerson, Chief of Motive Power and Equipment of the road. The boilers of the Delaware and Hudson locomotive were designed by John E. Muhlfeld, Consulting Engineer in New York.

The boiler of the *Baldwin* experimental locomotive No. 60 000 is shown on figure 22. It carries a pressure of 350 lb. per square inch. The firebox consists of a hollow cast-steel mud ring, two drums and 4-inch tubes forming two side walls and connecting the mud ring with the drums. There are no tubes in the back head. The combustion chamber is not built into the fire-tube boiler, but is a part of the firebox, separated from the firebox proper by a brick arch. This is supported by five arch tubes which are led from the upper drums to a transverse member of the mud ring. The two drums are directly attached to the back tube sheet of the fire-tube boiler.

The locomotive has three equal cylinders 27 × 30 inches of which the middle is the high-pressure cylinder, and the two outside are low-pressure cylinders, The ratio of volumes is 1 : 2. Each cylinder has its own independent valve motion.

The rated tractive force is 82 500 lb. The weight of the locomotive is 457 500 lb. and the weight on the drivers is 338 400 lb. The factor of adhesion is thus 4.1.

The locomotive underwent very exhaustive tests on the Altoona, Pa., testing plant. The consumption of steam per indicated horsepower showed a remarkable steadiness. It varied from 14.2 to 16.6 lb. per hour, which corresponds to an engine thermal efficiency of from 11.5 to 13.5 %. This is undoubtedly the result of combining high pressure with compounding and high superheat. The

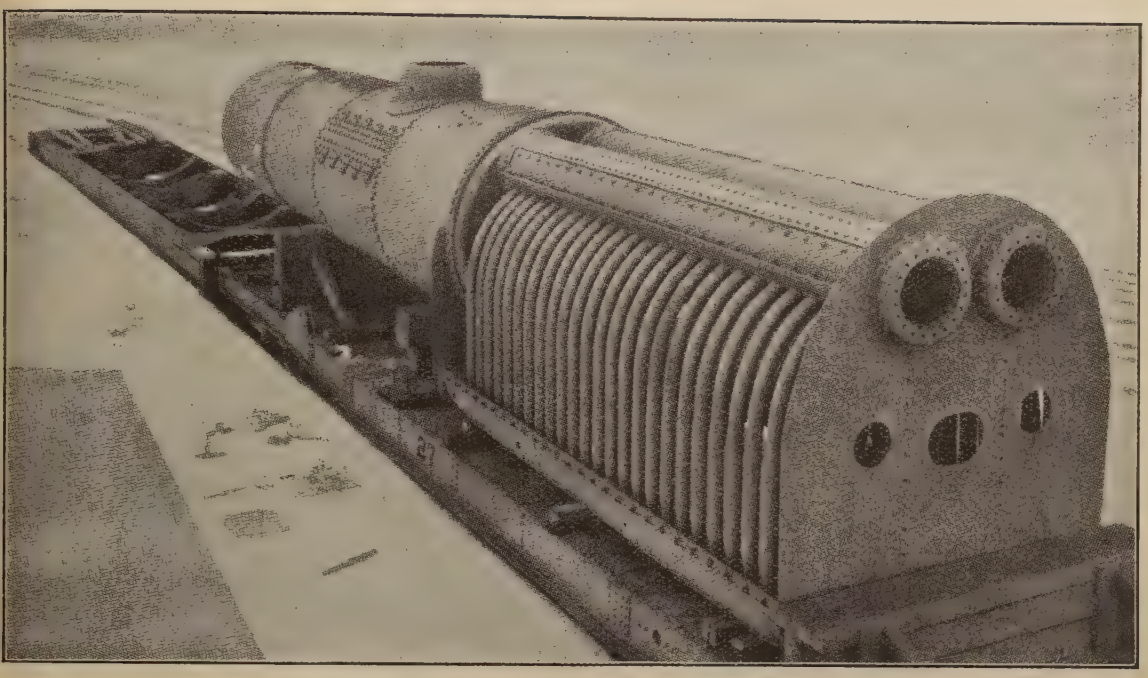


Fig. 22. — Baldwin Brotan boiler of experimental locomotive No. 60 000.

boiler efficiency varied from 71 % at a rate of firing of 47.6 lb. per square foot of grate area per hour to 51 % at a rate of 143 lb. per square foot. The effect of the feed water heater is not included in the above figures of boiler efficiency. The mechanical efficiency of the locomotive varied from 65.9 to 89.9 %, and the total overall efficiency of the locomotive from coal to drawbar pull on the test plant, feed water heater included, fluctuated between 5.6 to 7.8 %.

During the tests, a maximum tractive force of 74 764 lb. was obtained at a speed of 15.2 m. p. h. with a 90 % cutoff in the high-pressure cylinder. The actual factor of adhesion was thus 4.5. This tractive force, if referred to the two low-pressure cylinders only, corresponds to a mean indicated pressure of 58 % of the boiler pressure.

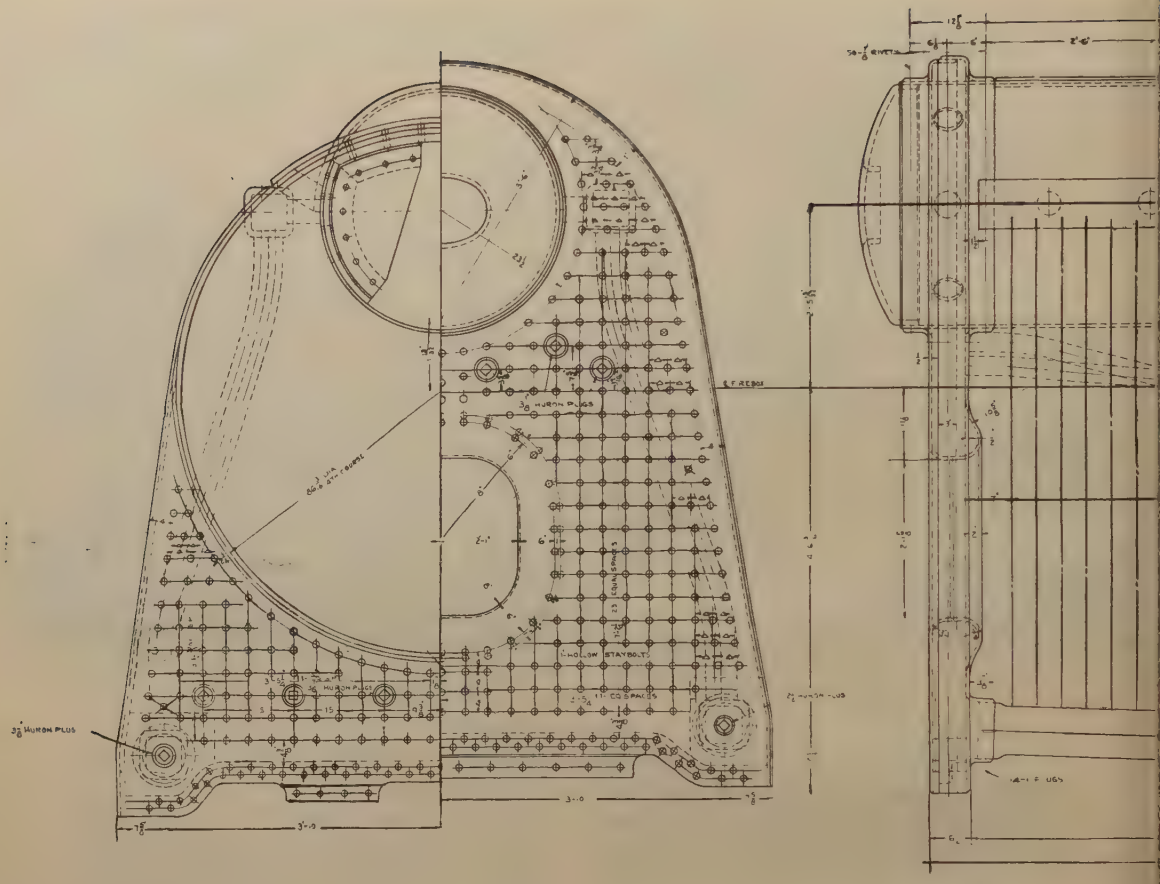
The maximum power of 4 515 I. H. P. was developed at a speed of 37.6 m. p. h. with an 80 % cutoff in the high-pressure cylinder and 50 % in each of the two low-pressure cylinders. As the weight of the locomotive is 457 500 lb., the weight per horsepower (actual) is 101.5 lb. (1).

The *McClellon* firebox on the *New York-New Haven* is built for a pressure of 265 lb. per square inch. It differs

(1) *Baldwin Locomotives*, April 1927, pp. 42-50.

Railway Mechanical Engineer, January 1927, pp. 8-11.

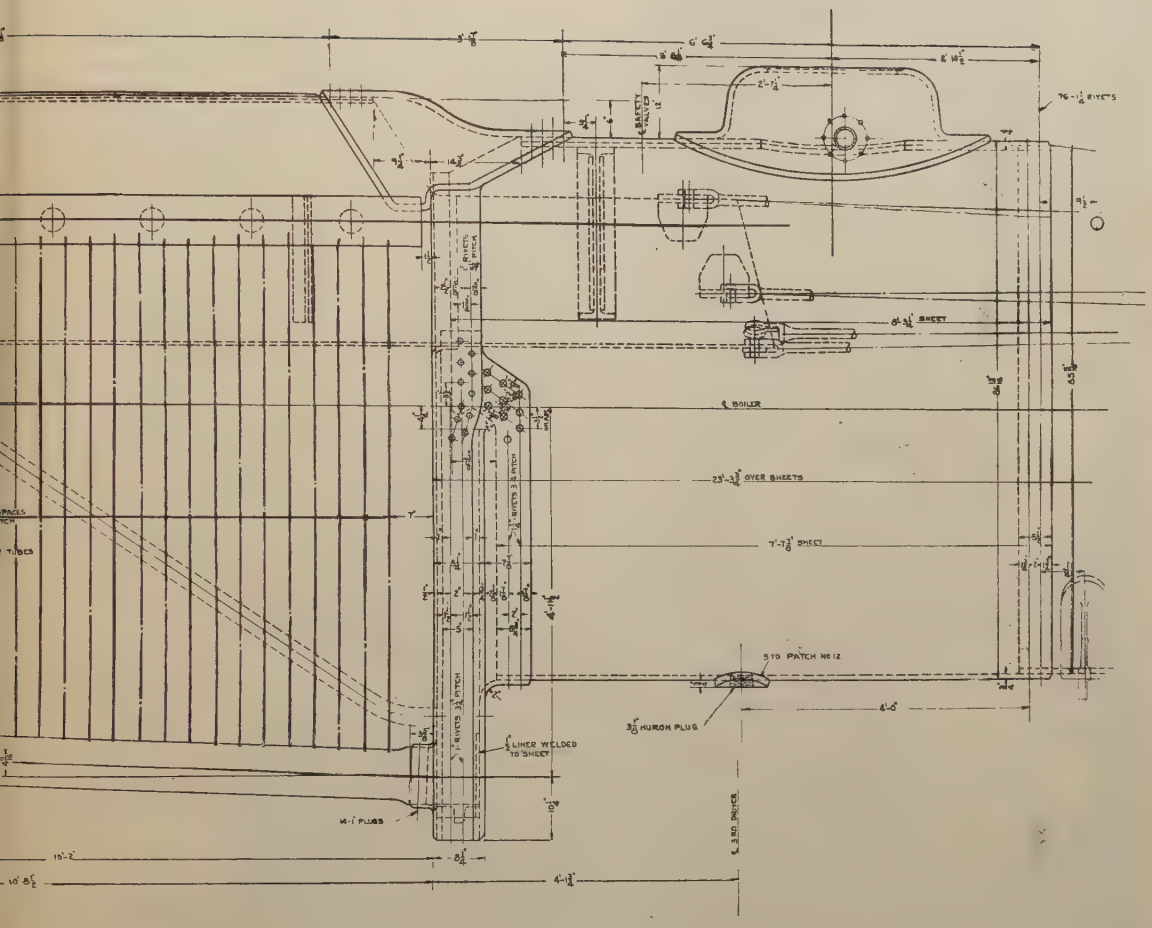
Locomotive No. 60 000, The Baldwin Locomotive Works, Philadelphia, 1926.



from the Brotan firebox in that it has three top drums riveted together and connected with the tube sheet of the fire-tube part. It further has a combustion chamber formed by the lower surfaces of the three drums and a series of tubes which merge into the extended rear course of the barrel, near the bottom. In order to connect these tubes with the mud ring and with the tubular part of the boiler, a trough is provided which extends underneath the shell of the boiler. The firebox is braced in such a way as to form a rigid girder-box enclosing the drums and mud ring, and thus relieve the tubes of stresses from unbalanced inside pressures (1).

In designing a water-tube firebox the *Baltimore & Ohio Railroad* had in view to develop a boiler which could be washed, and in which each water-tube could

(1) *Railway Mechanical Engineer*, March 1926, pp. 143-150.



be turbined (2) without the necessity for the workman to get inside the boiler. Several designs have been worked out, of which the latest is shown on figure 23. The firebox consists of a single longitudinal drum, 40 inches in diameter, two top longitudinal square headers, two bottom longitudinal headers, eighteen 4-inch circulating tubes connecting the drum with the two top headers (nine on each side) and two rows of 2-1/2 inch water-tubes between the top and bottom headers, these tubes forming the sides of the firebox. The top and bottom headers are provided with openings opposite each water-tube for rolling in and cleaning the tubes. The openings are closed by plugs. The firebox is completed by a front and back head made of parallel flanged boiler plates riveted together and held by staybolts.

(2) Cleaned inside by a scale cutting tool on a flexible shaft.

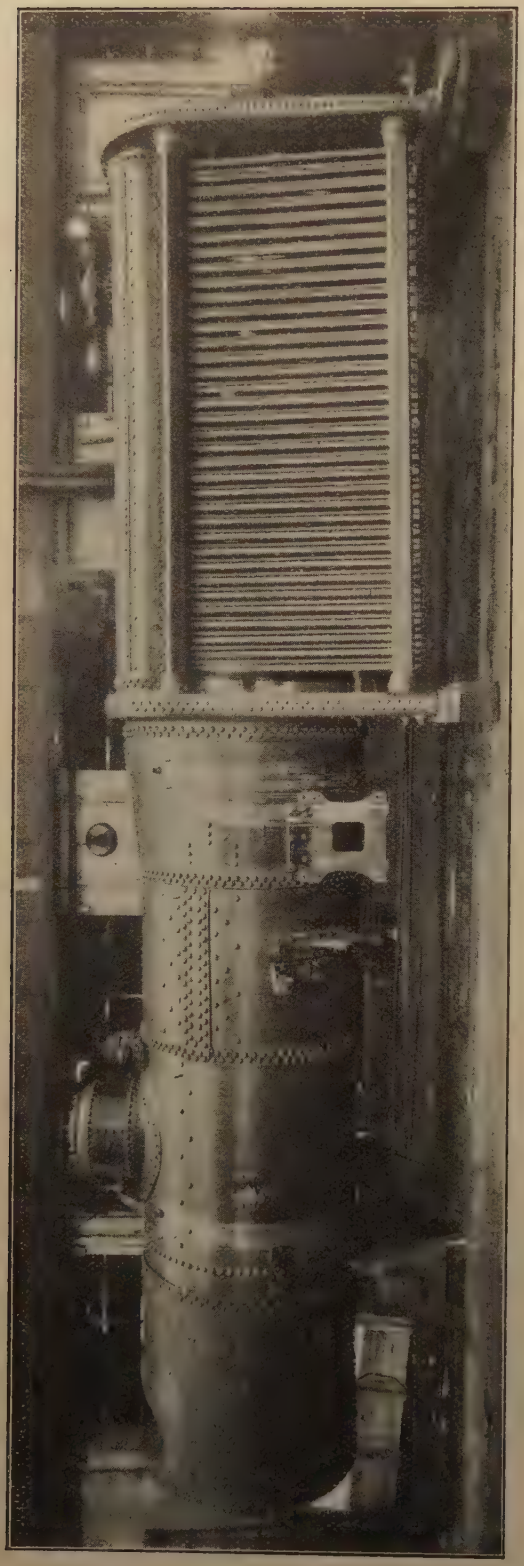


Fig. 24. — Emerson boiler for Baltimore and Ohio locomotive No. 4045.

In this type of firebox all crown sheet stays, radial stays and water space stays are eliminated; there are less than three hundred stays in the front and back head.

The Baltimore & Ohio Railroad originally built boilers with two longitudinal drums of 28-inch inside diameter. Figure 24 shows one of these boilers installed in a 2-8-2 locomotive, No. 4045, Class Q-1x, while figure 25 is a photograph of the locomotive itself. After building several of the double drum boilers it developed that it is very difficult to maintain the insulation between the two drums, principally due to vibration. In order to overcome this, the railroad built the one-drum boiler described above. It has been watching the performance of these boilers very closely and it is the railroad's opinion that the one-drum design as shown on figure 23 is the one which it will finally adopt. It is the present intention (July 1929) to build more of these boilers and put them in service, as complete fireboxes are needed on existing locomotive boilers.

The dates of building and placing in service the five water-tube boilers are as follows :

Class.	Number.	Type.	Date.
E-27x	2504	2-8-0	30 April 1927.
Q-1x	4045	2-8-2	9 September 1927.
E-27y	2700	2-2-0	15 March 1928.
P-9	5320	4-6-2	16 May 1928.
E-27z	2511	2-8-0	26 January 1929.

The first locomotive, after preliminary tests had been made, was placed in regular service in July 1927, on a very bad water district, on the Wheeling Division between Benwood and Fairmont, operating about 200 miles a day, and up to the present time (July 1929) has not given any undue trouble. It has been all the time in ordinary pool service, the same

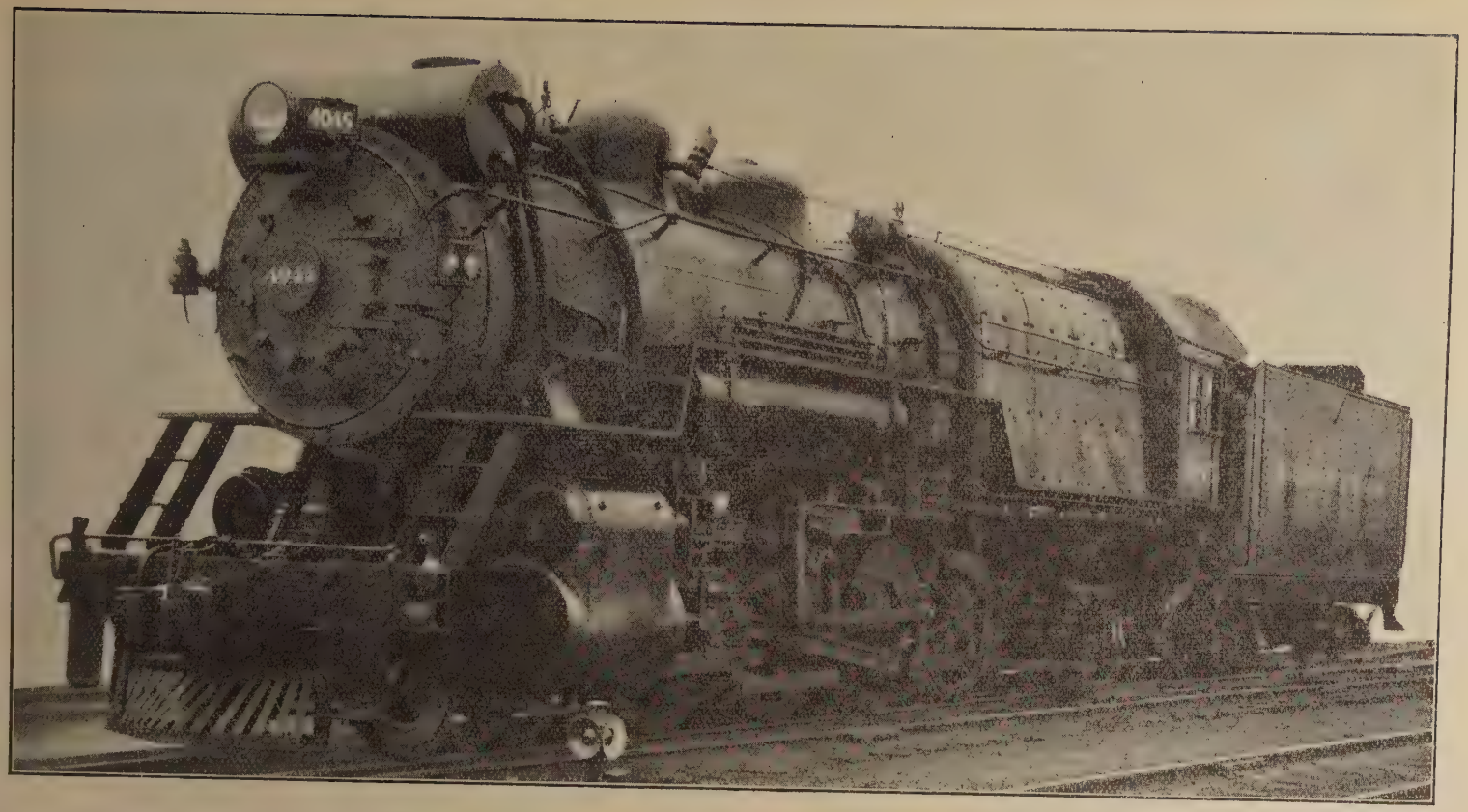


Fig. 25. — Baltimore and Ohio locomotive No. 4045 with Emerson boiler.

as all other locomotives. The boiler is washed and turbined (1) every thirty days, while the staybolt boilers in the same territory are washed every fifteen days.

In order to wash out the firebox, the plugs in the square headers are taken out and the tubes are cleaned and turbined. The time required for turbining and washing the water-tube boilers is no longer than that consumed in washing a conventional boiler with a staybolt firebox. The railroad states that when the water-tubes and headers are washed and turbined they are as clean as when the boiler left the builders' shops.

After locomotive No. 4045 was built, very careful dynamometer tests were run on the East End of the Cumberland Division of the Baltimore & Ohio Railroad between Keyser and Brunswick. Below, in table IX, are given three records of general results obtained at the tests, each record being an average of five round trips, in comparison with a record of dynamometer test of superheated locomotive No. 4299, which is of the same type and the same general construction as locomotive No. 4045 but has a conventional staybolt boiler, and 88 % maximum cutoff, Walschaerts valve gear.

Operation data regarding fuel consumption, cost of maintenance, are not available for the reason that the Railroad has not kept these items for locomotives with water-tube fireboxes separately from locomotives of ordinary type.

The principal dimensions of the two locomotives are given in table X.

The *Delaware & Hudson* placed in service two high-pressure locomotives built by the American Locomotive Company, *viz.* in 1924 the *Horatio Allen* with 350-lb. pressure, and in 1927 the *John B. Jervis* with a pressure of 400 lb. per square inch. These two locomotives are of the 2-8-0 type (1). They were designed by J. E. Muhlfeld, consulting engineer for the Delaware & Hudson, and in all essentials the two locomotives are alike, differing slightly in the size of the firebox, in the pressure and in such dimensions as were caused by these changes.

The Muhlfeld boiler, shown on figure 26, consists of two headers, each composed of two parallel flanged sheets riveted together. The headers are connected by four drums which project through the headers and are riveted to their flanges. The two upper drums have forward extensions riveted to a stayed saddle secured to the tubular boiler shell; the latter is riveted to the front flange of the first header. In order to provide for communication between the four drums and the headers, and between the top drums and the saddle each drum has circumferential ports between the two sheets of the header or saddle. The side walls are composed of 2-inch and 2-1/2 inch tubes (in the John B. Jervis of only 2-1/2-inch tubes) placed between the drums in several rows similar to a marine type construction; in the Horatio Allen in six staggered rows, and five in the John B. Jervis. The two engines are of the two-cylinder cross-compound type. Their cylinders are : in the Horatio Allen 23-1/2 inches and 41-inches by 30-inches stroke; and in the John B. Jervis 22-1/4 inches and 38-1/2 inches by 30-inches. This variation is due to the difference in

(1) See last foot note.

(1) *Railway Mechanical Engineer*, February 1925, pp. 78-86, and April 1927, pp. 207-211.

(*Editorial Note :* See *Bulletin of the Railway Congress*, February 1926, p. 130, and June 1927, p. 552.)

TABLE IX

Engine number	4 045		4 015		4 045		4 299	
Class	Q-1x		Q-1x		Q-1x		Q-1c	
Valve gear	Walschaerts		Walschaerts		Walschaerts		Walschaerts	
Date of test	Nov.-Dec. 1927 January 1928		Nov.-Dec. 1927 January 1928		Nov.-Dec. 1927 January 1928		August 1927	
Division	E. E. Cumb.		E. E. Cumb.		E. E. Cumb.		E. E. Cumb.	
East or Westbound	East	West	East	West	East	West	East	West
Kind of coal	Run of mine Gas		Run of mine Gas		Run of mine Gas		Run of mine Gas	
Lb. coal per drawbar H. P.-hour	2.22	2.42	2.20	3 06	2.13	2.69	2.74	3 30
Lb. coal per 100 ton-miles	3.64	10.20	3.78	12.34	3 63	10.70	4.37	13.24
Lb. coal per sq. ft. of grate per hour	49.15	55.92	50 27	70.76	49.33	64.91	54 37	65.5
Lb. water per lb. coal	8.00	7.86	8.02	7.33	7.79	7.43	6.04	5.75
From and at 212° F.	9.28	9.12	9.30	8.58	9.11	8.77	7.92	7.78
Lb. steam per drawbar H. P.-hour.	16 17	17.06	15.35	18.83	15 02	17.29	17.19	19.59
Average drawbar H. P.	1 626	1 699	1 682	1 698	1 691	1 774	1.402	1 389
Average drawbar pull, lb.	26 779	24 825	27 453	28 241	27 600	25 444	26.067	23 497
Time (moving)	5 h. 17 m.	5 h. 2 m.	5 h. 29 m.	4 h. 55 m.	5 h. 13 m.	4 h. 42 m.	6 h. 10 m.	5 h. 40 m.
Number of cars	72	89	72	90	67	89	68	87
Adjusted tonnage (1)	6 120	2 566	6 202	2 554	6 038	2 587	6 035	2 471
Actual tonnage (1)	5 040	1 943	5 122	1 924	5 041	1 964	5 019	1 859
Total coal, lb.	20 100	21 700	21 200	26 000	20 800	23 000	23 931	26 731
Total water, lb.	138 800	145 814	142 000	157 340	133 210	144 130	144 500	153 800

(1) 1 ton = 2 000 lb

Table X.

Engine number	4 045	4 299
Class	Q-lx	Q-lc
Type	2-8-2	2-8-2
Cylinder diameter and stroke	26 1/2" × 32"	26" × 32"
Diameter of drivers, inches	64	64
Boiler pressure, lb. per sq. in.	250	190
Diameter of boiler, inches	78	78
Tubes, number and diameter	265 — 2-1/4"	218 — 2-1/4"
Flues, number and diameter	40 — 5-1/2"	34 — 5-1/2"
Length of tubes, feet	16	21
Water tubes, number	138	—
Water tubes, outside diameter	2-1/2"	—
Water tubes, average length	5'-7"	—
Heating surface, firebox, sq. ft.	603	228
Heating surface, tubes and flues, sq. ft.	2 854	3 740
Heating surface, total, sq. ft.	3 457	3 968
Heating surface, superheating, sq. ft.	842	833
Grate area, sq. ft.	73.5	70.0
Tractive effort, lb.	65 400 (1)	54 600 (2)
Factor of adhesion	3.81	4 00
Weight in working order, lb.	334 000	276 000
Weight on drivers, lb.	249 000	219 000

(1) Based on 60 % cutoff. — (2) Based on 88 % cutoff.

pressures. The rated tractive force in both cases is a little over 70 000 lb. for compound work. At starting, when the engine can work simple, the tractive force is 85 000 lb. in addition to 18 000 lb. developed by the auxiliary locomotive on the tender. In actual service the Horatio Allen developed a tractive force of 75 000 lb., in compound, at five miles an hour, which corresponds to a combined mean indicated pressure referred to the low pressure cylinder of 48.5 % of boiler pressure. The actual factor of adhesion is 3.93; the estimated is 4.18, the weight on drivers being 295 000 lb.

Special tests made with the Horatio Allen on the Delaware & Hudson showed that the locomotive is very economical. An average of five runs made with a dynamometer car between Oneonta, N. Y.,

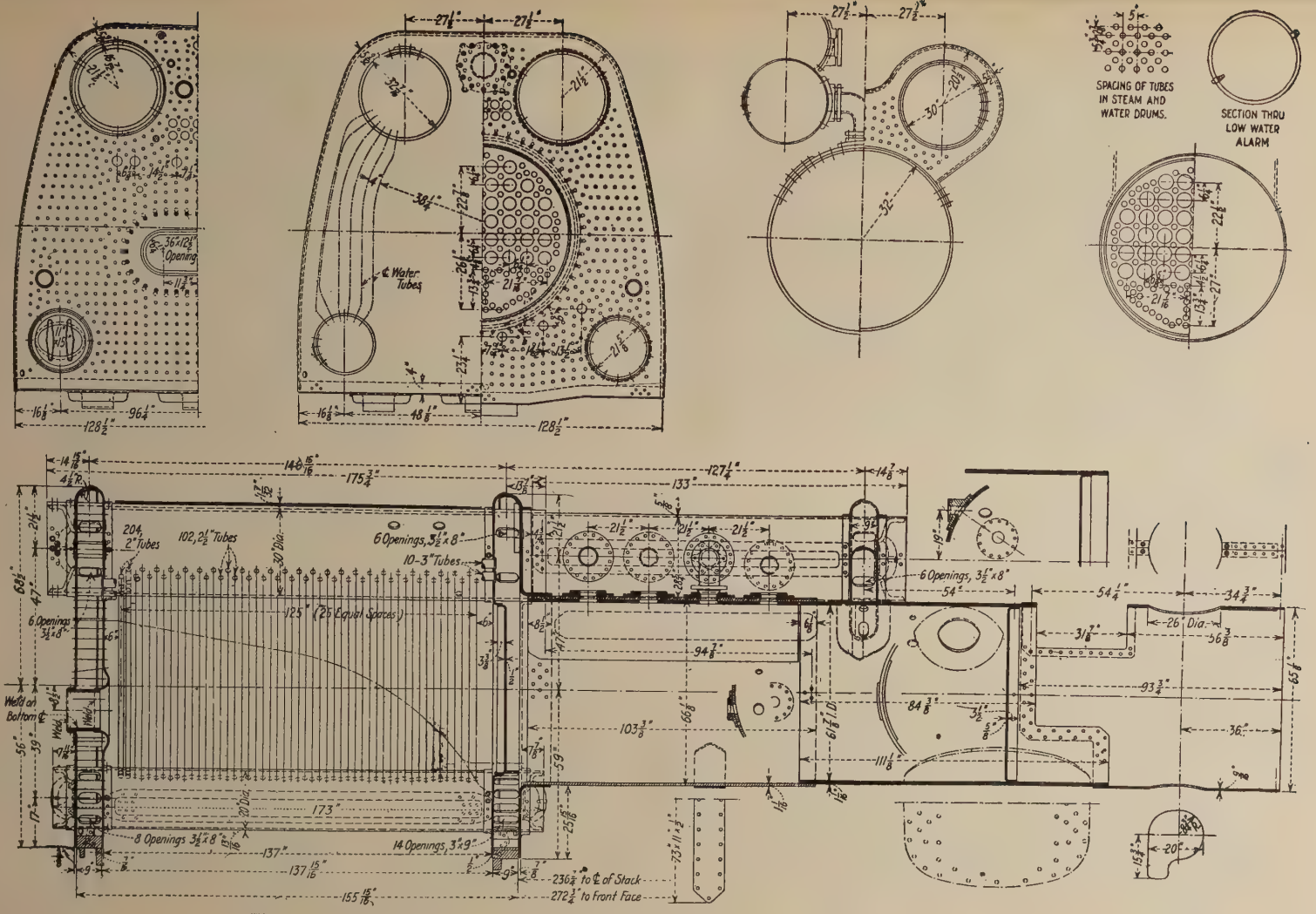


Fig. 26. — Muhlfeld boiler for the Delaware and Hudson locomotive « Horatio Allen » No. 1400.

and Dante, over a distance of 28.76 miles with predominating grades of 0.5 %, resulted in figures (1) shown in the table.

Results of dynamometer car tests of the « Horatio Allen ».

Gross tons	3 125
Average speed, m. p. h.	16.5
Rate of firing, lb. per sq. ft. per hour.	57.4
Equivalent evaporation	10.7
Boiler efficiency, per cent	75.8
Average cut-off (high pressure), per cent	63.6
Average I. H. P.	1 814
Dry coal per I. H. P.-hour, lb. (auxiliaries included)	2.197
Same per drawbar H. P.-hour	2.312
Overal thermal efficiency of locomotive, per cent	8.02

Note. — The locomotive has no feed water heater.

No figures on the John B. Jervis have been communicated so far, but according to the railroad, the indications are that this locomotive is even more economical than the Horatio Allen.

The two locomotives are used in freight service on the Susquehanna Division of the Delaware & Hudson Railroad, between Oneonta and Mechanicville, with grades up to 1.4 %. The fuel is either bituminous coal, or a mixture of coal and anthracite. The analysis of the two kinds of coal is as follows :

	Bituminous coal.	Anthracite.
Moisture, per cent	1.00	1.00
Volatile, per cent	36.00	5.50
Fixed carbon, per cent	54.00	78.00
Ash, per cent	9.00	15.50
Sulphur, per cent	2.00	1.75
Heat content, B. T. U.	14 000	12 500

Water on the division is of fairly good quality : it contains mostly carbonates of lime (up to 3.347 grains per U. S. gallon of 231 cubic inches), sodium and potassium sulphates (up to 1.823 grains per U. S. gallon), sodium and potassium chlorides (up to 1.02 grains), silicon (up to 1.694 grains) and other less important ingredients. The amount of total mineral solids is between 5.256 and 8.293 grains per U. S. gallon, and of organic matter between 0.350 and 0.584 grain per U. S. gallon. The total of incrusting solids is only 2.460 to 5.785 grains per U. S. gallon of 231 cubic inches.

Some information from a discussion on high pressure locomotives, presented by Mr. George S. Edmonds, Superintendent of Motive Power of the Railroad, before the 1928 Annual Meeting of the American Society of Mechanical Engineers, will be of interest. Up to the date of the discussion (5 December 1928), the Horatio Allen (locomotive No. 1400) and John B. Jervis (No. 1401) had a mileage of 95 000 and 40 000 respectively. Nevertheless, it had not been necessary to renew a broken staybolt in any of the stayed flat surfaces of the front and back headers. Several bolts had to be changed to correct alignment. Locomotive No. 1400 had been then in service 4-1/2 years; No. 1401, a year and ten months.

No work had to be done in the upper drum connections with the water-tubes. In the lower drums, some work was necessary on the inner row of tubes. At the time of shopping of the Horatio Allen in November 1927, after a mileage of 74 000, a full inner row on each side was applied.

Caulking of seams was negligible on engine No. 1401, which had flexible staybolts in the front sheet of the front header (throat sheet). Some caulking was necessary on the Horatio Allen, which had no flexible staybolts. Occasionally a drum rivet required attention.

(1) These data became available through the courtesy of G. S. Edmonds, Superintendent of Motive Power, Delaware & Hudson.

No cracks had been noticed in engine No. 1401. In engine No. 1400 two cracks in the back header on the firebox side, a little over one inch long, and nine in the front header, about one-half inch long, also on the firebox side, had been found. The cracks had started from staybolt holes. They were welded and new bolts applied.

The boilers generate steam very freely, giving no difficulty in maintaining full boiler pressure, even when boosters are applied on ruling grades. The superheat is rather low — on the Horatio Allen a maximum temperature of 600° F. has been realized, but in average operation 550°-575° F. represents more nearly actual temperatures. The engine is deficient in this respect, and in subsequent designs provisions have been made to obtain higher temperatures.

The amount of scale which accumulates in thirty days is very small. This is probably due to the rapid circulation in the water tubes and to the comparative softness of the water. While it is true that it takes somewhat longer to wash these boilers than those of the ordinary type, developments are now in progress which, it is expected, will lead to making the difference very small.

No trouble with cylinder and piston rod packing had been experienced. On engine No. 1401 cylinder packing was renewed after 38 900 miles, and the piston rod packing was still satisfactory after thirteen months of service.

There were very few engine failures on the road chargeable to the boilers. The first shopping of the « Horatio Allen » was after 74 000 miles and 3-1/2 years of service. The « John B. Jervis » was scheduled for shopping after 65 000 to 70 000 miles, and two years of service.

The mileage of the engines was not high — 95 000 miles on No. 1400 in four years and six months, and 40 000 miles on No. 1401 in one year and ten months. This was due to several causes :

1. The engines had to be out of service a great deal for experimental changes;

2. In view of weight limitations the use of the engines had to be confined to but a portion of one division, pending strengthening of some bridges;

3. In order to eliminate the variation in handling of experimental engines and to render crew observations as valuable as possible, the locomotives were operated with assigned crews and the mileage was, therefore, reduced.

Operation data regarding fuel consumption, cost of maintenance, are not yet available, but it is the opinion of the Railroad that the experience with the water-tube fireboxes warrants the further use of fireboxes of this type, as is evidenced by the recent purchase of a third locomotive of this type from the American Locomotive Company, « the James Archbald », No. 1402. The boiler of this locomotive (fig. 27) carries a still higher pressure — 300 lb. per square inch. It is of the same Muhlfeld type, differs very little in design or dimensions from the boiler of the John B. Jervis (No. 1401), but it does differ in the use of alloy steels. The shell plates of the fire tube boiler and of the front top drums are of silicon-manganese steel; the rear top drums and the bottom water drums are of nickel low carbon steel. The water tubes next to the fire are of special Allegheny heat-resisting steel; tubes in other rows are of cold drawn seamless steel. The boiler tubes and flues are of nickel steel. The rest is of carbon steel.

The locomotive was completed and delivered to the Railroad in April 1930. Figure 28 gives a view of the locomotive. It is the intention of the Railroad, after

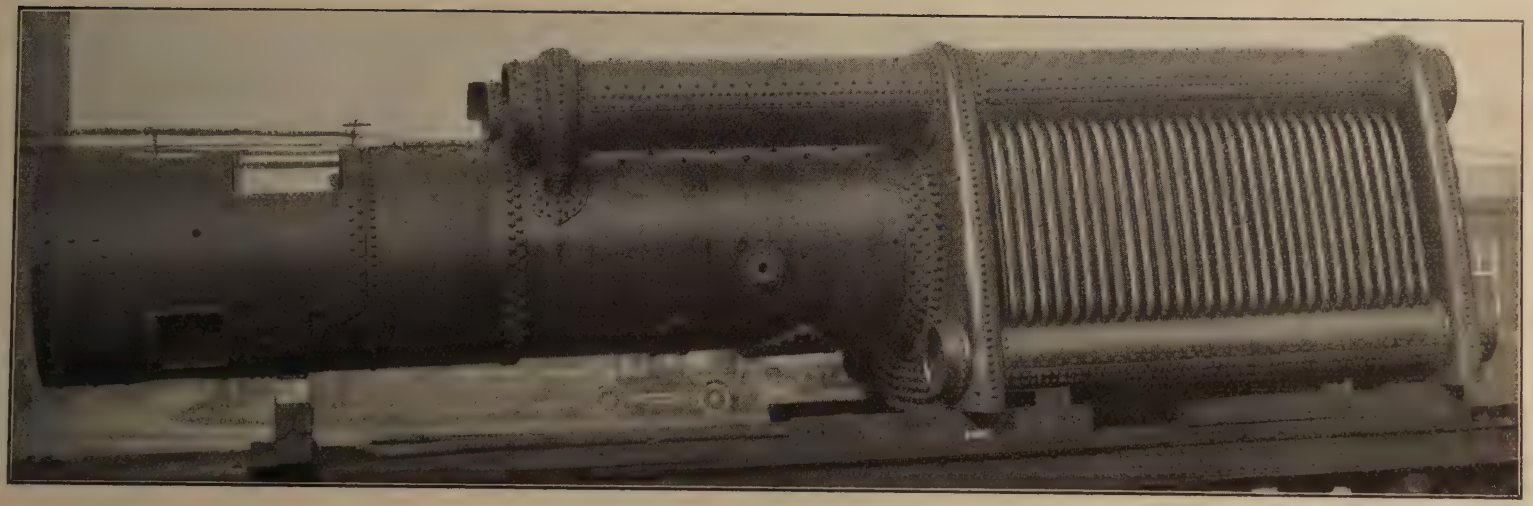


Fig. 27. – Muhlfeld boiler for Delaware and Hudson locomotive « James Archbald » No. 1402.

Fig. 28. — Delaware and Hudson locomotive « James Archbald » No. 1402.

TABLEAU XI.

Locomotive	« Horatio Allen »	« John B. Jervis »	« James Archbald »
Road	Delaware and Hudson	Delaware and Hudson	Delaware and Huds n
Gauge of track	4 ft. 8 1/2 in.	4 ft. 8 1/2 in.	4 ft. 8 1/2 in.
Type	2-8-0	2-8-0	2-8-0
Cylinder, high pressure, inches	1 × 23-1/2	1 × 22-1/4	1 × 20-1/2
Cylinder, low pressure, inches	1 × 41	1 × 38 1/2	1 × 35-1/2
Cylinder, stroke, inches	30	30	32
Diameter of driving wheels, inches	57	57	63
Boiler pressure, lb. per sq. in.	350	400	500
Tractive effort, comp., lb.	70 300	70 300	70 300
Tractive effort, simple, lb.	84 300	84 300	84 300
Tractive effort, booster, lb.	18 000	18 000	18 000
Grate area, sq. ft.	71.4	82.0	81.9
Number of flues and diameter, inches	42 × 5-3/8	52 × 5-1/2	52 × 5-1/2
Number of tubes and diameter, inches	145 × 2	101 × 2	155 × 2
Length of tubes and flues, feet	15	15	15
Heating surface, total firebox, sq. ft.	1 124	1 145	1 048
Heating surface, total boiler, sq. ft.	3 200	3 117	3 439
Superheater heating surface	579	717	1 037
Weight on drivers, lb.	298 500	298 000	300 000
Weight total in work. order, lb.	348 000	340 000	356 000

1699
V—259

the locomotive is broken in, to make exhaustive tests in comparison with locomotives of the ordinary type.

The principal dimensions of the three locomotives are given in table XI.

CONCLUSION.

The experience with water tube fireboxes in America is very interesting and promising, but in view of the shortness of time of the experience and of the limited territory where it took place, and especially in view of the lack of complete information regarding the operation of the locomotives, it is yet too early to draw any definite conclusions as to the serviceability and advantages of fireboxes of this type.

[625. 142.4]

A new type of ferro-concrete sleeper.

The Prot sleeper [1],

by Marcel PROT,
Engineer for Bridges and Roads.

Figs. 1 to 10, pp. 1705 to 1716.

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a) General features;
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e) Weight;
f) Handling;
g) Repairs;
h) Price.
Summary.
Conclusions.
Instructions for laying the Prot sleeper and for its maintenance.

I. — The question of ferro-concrete sleepers.

After a long period during which the art of construction scarcely knew anything but stone and wood, the end of the nineteenth century and the beginning of the twentieth saw these materials gradually being replaced by steel in numerous applications. Steel is rapidly being replaced today by ferro-concrete, especially in the construction of bridges, framed structures and foundations. For foundations in bad ground, wood « rafts » and later steel « rafts » have been used in succession, whereas nowadays no one would ever think of using anything but concrete, either reinforced or not.

The railway sleeper, which is at once the foundation and the girder of the permanent way, is passing through the same stages although somewhat more slowly.

Undoubtedly, up to the present, timber has been a very suitable material for sleepers, but this will very soon be the case no longer. Having become increasingly more expensive to buy and to maintain, timber is essentially perishable, despite costly treatment, so much so that new countries, where the climate is hot, have had to dispense with it in equipping their railways. Moreover, although timber answered well to the loads and speeds of yesterday, it is begining to be doubted whether its necessarily restricted dimensions and its primitive method of rail attachment answer as well to the loads and speeds of the present day, or will answer *a fortiori* to those of tomorrow, and it might be asked whether the exclusive preference of which timber is sometimes made the object is not due in part to custom and to too great a distrust with respect to new solu-

tions of the problem which will soon have to be found.

The steel sleeper, which is scarcely less perishable than the timber sleeper, does not impart a really satisfactory stability to the track, it is expensive to purchase and maintain and the rail attachment is still distinctly defective.

Ferro-concrete, with all the abundance and flexibility of its resources, provides a solution and ought to enable some progress to be made in this connection as it has done in many others.

It is true that only a few years ago some people still regarded the ferro-concrete sleeper as an Utopian idea. Its cost price was also very much greater than that of the timber sleeper, which it had not yet equalled from the technical standpoint, and its long life was the only advantage to be looked for in the distant future.

Conditions at the present time are very much different. Already considerable quantities of ferro-concrete sleepers have been given a trial, especially in France, and the results obtained, although often not perfectly satisfactory, have been sufficiently encouraging to convince even the most sceptically minded of the possibility of replacing timber by ferro-concrete. On the other hand, the difference in price between the one and the other has diminished in a remarkable manner, and if the increase in price which timber and creosote, which are ever becoming more in demand, have undergone in recent years still continues, we are on the eve of seeing the ferro-concrete sleeper become unquestionably more economical than the timber sleeper.

At the present moment, therefore, the ferro-concrete sleeper is invested with an interest which it has never before possessed, and which is forcibly emphasised by the numerous tests which have been organised of late in all parts of the world.

Still — and this is a conclusion which follows clearly from the most recent articles on this question (1) — the very fact of the difference in opinions regarding the types which have been tested and the large number of new types which have recently been proposed, prove incontestably that the *ferro-concrete sleeper which is absolutely satisfactory from the technical point of view has yet to be constructed.*

II. — Evolution of the ferro-concrete sleeper.

When in any branch of construction, a material which has been used for a long time is replaced by a new material, it may often be observed that during a period of transition, which is frequently fairly long, the new material is still given the shapes of the old material before it is given the new and more rational shapes which are better adapted to its properties, even when these properties differ perceptibly from those of the old material. Ferro-concrete sleepers form a remarkable example of this slowness of evolution.

The timber sleepers, employed one might say ever since the origin of railways, have the shape of a parallelopiped, which is rendered necessary on account

(1) *Bulletin of the International Railway Congress Association :* Reports drawn up for the Madrid Congress : No. 1, by Messrs. Jullien and Claise (November 1929 number, p. 1959). No. 2, by Mr. F. B. Freeman (May 1929 number, p. 433). No. 3, by Mr. E. Krick (December 1929 number, p. 2975). Mr. Freeman states : « ... a satisfactory design is not available. It is essential that experiments be continued to develop a satisfactory design ».

of their very nature, the moderate size of the trees from which they have been made and the easiest and most economical method of selling timber. This shape, which is obtained directly by sawing, is both the simplest and the least expensive, and besides is well suited to the conditions under which the sleeper has to perform its duties.

When the idea first arose of replacing timber for sleepers by ferro-concrete, an essentially different material, it is curious to note that an attempt was made to reproduce in ferro-concrete the shape and dimensions of the timber sleeper. *Now the least that can be said is that this shape and small size, unavoidable in the case of timber, are by no means necessary in the case of ferro-concrete.*

Doubtless, certain constructors have already appreciated this anomaly for they have sought to separate the function of transmitting the vertical stresses from the function of providing a cross-tie between the rails, and the types of sleeper in which this two-fold function is entrusted to two distinct parts, the head and the cross-piece, represent an effort to discover a more rational solution. There still remains much to be done, however, in connection with this application, and the present sleepers appear to be far from making full use of all the benefit that is to be got from ferro-concrete as a substitute for timber.

In brief, if we admit that the formula which was suitable for timber is probably not that which is adapted fo ferro-concrete, if we make an effort to abandon the old ideas which we are tempted to find satisfactory simply because they are familiar, and if we refrain from regarding some solutions as final, which a relative degree of perfection leads us to regard for the time being as acceptable, *we shall recognise that the really rational solution of the problem of the ferro-concrete sleeper is still to be found as regards both the sleeper itself and the method of fixing the rail.*

III. — The rational ferro-concrete sleeper.

The sleeper in general performs a three-fold function :

— transmission of the vertical forces;

— transmission of the horizontal forces;

— maintaining the distance between two lines of rails.

At the present time, the dimensions of the timber sleeper may be regarded as final and could not, at least not economically, be much greater than what they are now. The surface of support on the ground thus obtained transmits considerable vertical pressures which would be inadmissible for most kinds of ground, and which are distributed over a greater area by placing a bed of ballast made of selected material between the ground and the sleeper.

In order not to increase excessively the thickness of this bed of ballast, it has become the common practice to place beneath it another lower layer of sand or gravel, which distributes the pressures over a much greater area and so reduces them to a value which is permissible even for the worst ground.

Apart from the vertical stresses, the rail transmits to the sleeper horizontal, longitudinal and lateral stresses. The ballast then intervenes in transmitting these stresses to the ground. The sleeper is held to the ballast by adhesion, the ballast supporting the sleeper, while the sleeper bears against the ballast surrounding it by the thrust of its lateral faces or ends.

Hence it is not the timber sleeper alone which transmits to the ground the different forms of pressure exerted by the rail, but the combination formed by the sleeper and the ballast together.

Finally, the sleeper has to maintain the distance between the two lines of rails. We know that, in short radius curves, the timber sleeper has some difficulty in performing this duty, the coach screws becoming loose or being torn out, and the fibres of the timber beneath the rail flange, where the timber is subjected to the greatest load, being crushed excessively.

In view of the continued increase in the loads and speeds, the efforts which have been made to maintain the stability of the track consist in increasing the thickness of the ballast (tamped layer and bottom layer) and in placing the sleepers closer together. There is obviously no other solution possible with the timber sleeper, which, as was stated before, cannot be much different from what it is.

In this respect, however, ferro-concrete affords resources which are not offered by timber, and a rational ferro-concrete sleeper ought to utilise all these resources in order to perform in the best possible manner the three-fold duty which has devolved upon the sleeper.

This three-fold duty, which the timber sleeper cannot perform by itself, can be assured very effectively by the ferro-concrete sleeper provided that it is made of the proper shape and size. It is capable of providing by itself a bearing surface equal to, and even greater than that provided by the timber sleeper and the ballast bed combined.

The settling of sleepers, a serious factor in maintenance work and the result of the flexibility of the timber, may be avoided if advantage is taken of the rigidity which a ferro-concrete sleeper may possess.

Finally, if the wood screw constituting the coach screw is justifiable for fixing the rails to timber sleepers, it is obvious that its application to ferro-concrete sleepers, to which it is difficult to adapt, is merely an unjustified extension of old customs. On the other hand, a system of fixing the rail which is really adapted to ferro-concrete sleepers may possess qualities of strength, stability and tightness greater than those possessed by the coach screw in the best timber sleeper.

IV. — The Prot sleeper.

In the Prot sleeper, which is an entirely new type of sleeper, as regards both its conception as a whole, its shape and the rail fastening, these various resources of ferro-concrete are made use of and a solution of the problem is obtained. This sleeper appears to possess important technical and economical advantages.

a) *General features.* — The Prot sleeper is a hollow ferro-concrete sleeper about 2.70 m. (8 ft. 10 5/16 in.) long, 0.40 m. (1 ft. 3 3/4 in.) wide at the base and 0.27 m. (10 5/8 inches) thick [1], the use *of which, even if it does not permit the ballast to be dispensed with entirely, enables the layer of ballast called the « tamping » layer to be considerably reduced.*

In fact, by virtue of these dimensions, the Prot sleeper has a lower bearing surface greater than 1.00 m² (10.76 sq. feet), whereas a timber sleeper of an average width of 0.24 m. (9 7/16 inches), tamped for 0.35 m. (1 ft. 1 3/4 in.) on either

(1) These dimensions are merely given to fix an order of magnitude and are not rigidly compulsory, since the exact dimensions must be determined in each case according to the conditions of service.

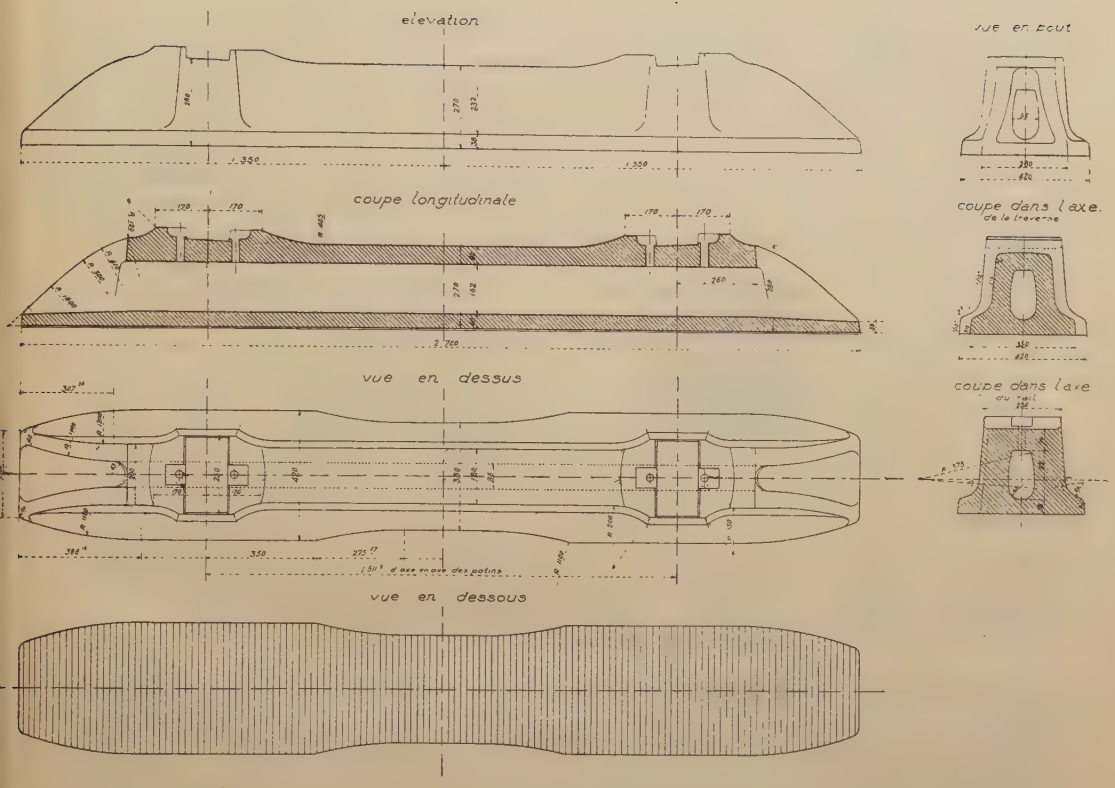

Fig. 1. — Prot ferro-concrete sleeper, patented in France and abroad.

Explanation of French terms: Coupe dans l'axe, etc... = Section along the axis of the sleeper. — Coupe dans l'axe du rail = Section along the rail axis. — Coupe longitudinale = Longitudinal section. — Vue en bout = End view. — Vue en dessous = View from below. — Vue en dessus = View from above.

side of the rail axis, has a bearing surface of only 0.34 m² (3.65 sq. feet), since the distribution produced by a bed of ballast averaging 0.15 m. (6 inches) thick under the sleeper does not appear to extend over an area very much greater than 0.60 m² (6.46 sq. feet) (1).

Under these conditions, there is no necessity to place beneath the sleeper a thick bed of selected and expensive ballast of broken stone, and it is sufficient to allow the sleeper merely to rest on a bed of sand, gravel, etc., which only requires to be of any thickness on really bad ground, and may be reduced to a mere conditioning bed of a few inches if the ground is good.

In point of fact, the material of the ballast is not altogether absent from the permanent way. It has merely been incorporated in, and so to speak made part of, the sleeper itself in an incomparably more efficient and reliable form, *since the Prot sleeper by itself provides a bear-*

(1) Even if it is assumed that the entire surface of the timber sleeper plays an effective part, we still only obtain a surface of distribution under the tamped layer of the order of 1 m² (10.76 sq. feet).

ing surface which is distinctly greater, more stable and more efficient than that formed by the combination of the timber sleeper with its ordinary bed of tamped ballast.

Of course, in order to obtain a satisfactory conditioning of the floor and a better distribution of the pressure, a certain thickness of ballast can always be placed under the sleeper; in fact on clay floors, the thickness *ought* to be considerable, but what one may say is that, under any given conditions, the Prot sleeper by itself will be equivalent to the combination of the ordinary sleeper with a ballast bed 0.15 m. (6 inches) thick,

Fig. 2.

and other things being equal, it will always be possible with the Prot sleeper to save this 0.15 m. (6 inches) of ballast.

b) *Stability.* — The conditions of stability of this sleeper have been studied in detail in a paper (1), where the reader will find all the useful particulars, especially relating to a method of calculating ferro-concrete sleepers conforming more closely to experience than the methods generally employed heretofore.

At this place, the writer will confine himself to summarising the consequences of the general features of the Prot sleeper in so far as concerns its behaviour in the track.

1. Its large bearing surface exerts on the elements lacking in cohesion placed beneath it a very much lower pressure per unit area than the pressure exerted by the ordinary sleepers, and consequently much less liable to permanently deform those elements, that is to say, to cause settling of the sleeper.

2. Its length of 2.70 m. (8 ft. 10 5/16 in.) results in a much flatter deformation curve and is in consequence less favourable to settling than that corresponding to a length of about 2.40 m. (7 ft. 10 1/2 in.).

3. Its thickness of 0.27 m. (10 5/8 inches), equivalent to the sum of the thicknesses of the timber sleeper and the layer of tamped ballast, gives it a rigidity which tends to equalize the pressures it exerts on the ground and which also tends to flatten the deformation curve, a double condition which is still further adapted to reduce settling.

4. Finally, it should be borne in mind that, for an equal pressure, a large surface has a lesser tendency to deform the ground than a small surface.

5. Whereas the present sleepers, and above all, timber sleepers resist often in a very precarious manner the horizontal efforts, which manifest themselves chief-

(1) M. Prot : *Note on the calculation of ferro-concrete sleepers* (see appendix).

ly by the creeping and sinusoidal deformation of the track, the Prot sleeper, on the contrary, is designed to afford an effective resistance to these efforts. By its own weight, by the weight of the filling of gravel which loads its edges, by its extensive bearing surface, and by the ribs on its lower face, it grips the ground firmly, and in addition, its large base tends to protect the ground from damp and to compress it instead of mainly bearing, as does the timber sleeper, on the movable ballast surrounding it.

Although, in combating *creeping*, it has been possible to unite the rails and sleepers together in a suitable fashion, it has not been possible in practice hitherto to prevent completely the creeping of the sleepers in somewhat difficult cases. It may be supposed that *in this respect, the Prot sleeper will offer a resistance which hitherto no sleeper has been able to offer.*

6. Finally, owing to the fact that the deformation of the ground and the sleeper remains very slight, that of the rail itself is also diminished, and it may be concluded that this will result in less fatigue of the rail, a reduction in the number of fractures and an improved behaviour of the track, an advantage to be borne in mind in view of the continual increase in loads and speeds.

For the purpose of summarising and to fix one's ideas, it may be pointed out that it follows from what has been said that where the timber sleeper settles by *5 or 6 mm. (3/16 to 1/4 inch)*, the Prot sleeper, under the same conditions will settle by *less than 1 mm. (3/64 inch)*, an important consideration as regards permanent way maintenance.

c) *Method of rail attachment.* — The longitudinal cavity of the Prot sleeper enables a system of rail attachment to be designed which is remarkably simple and robust and which is *really adapted to ferro-concrete.*

This attachment consists for each rail, in the case of the flanged rail, of two bolts passing through two suitable holes, in the upper part of the sleeper. These bolts bear against the underside of the upper part of the sleeper by means of an elastic plate (1), and clamp the rail by means of two clips.

It will be seen at once that the attachment *thus constituted* is entirely independent of the sleeper and that it may be assembled and dismantled with ease without affecting the sleeper.

Owing to the possibility of accommodating an elastic plate in the recess, the attachment may be tightened in a much more effective and permanent manner even than that obtained by fixing the rail to a timber sleeper by coach screws, without any possibility of the rail canting over, widening of the track or jumping of the rail on the sleeper. To provide some idea of the functions of this elastic plate, it suffices merely to point out that the load required to crush it completely is about 2 500 kgr. (5 510 lb.), while for a good spring washer of the ordinary type, the crushing load does not exceed 150 kgr. (330 lb.).

This attachment may be used with the same degree of ease and the same advantages for fixing the chairs of double-headed rails.

It is an exceptionnally simple and convenient matter to place this attachment

(1) The services rendered by these elastic plates (Reiss plates) for locking fishing plates are well known. The railways using them have practically been able to do away with the periodical rounds required for tightening these bolts.

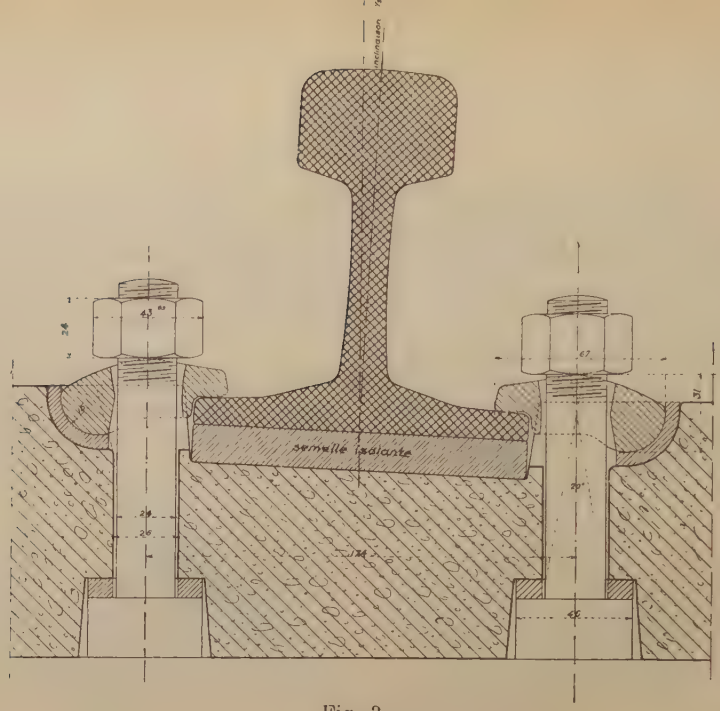

Fig. 3.

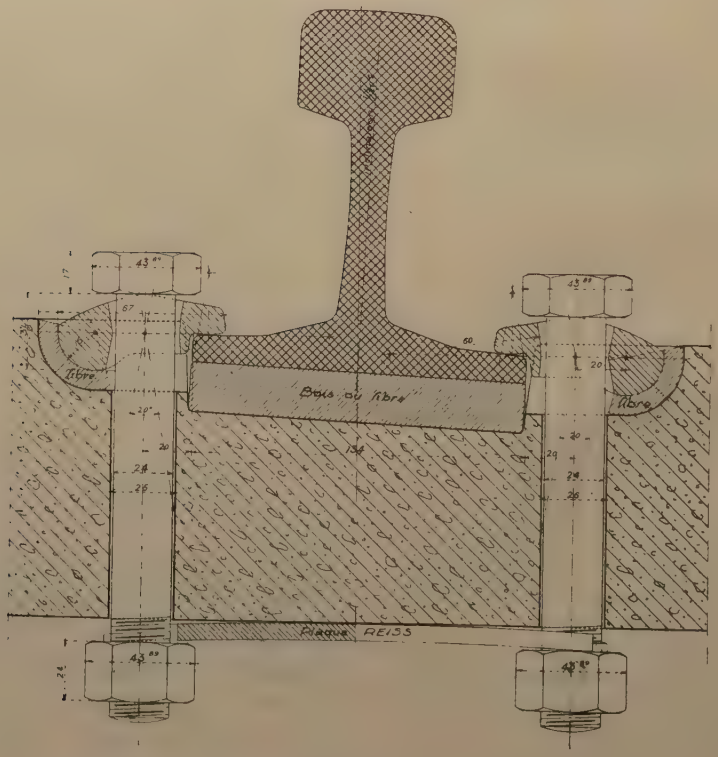

Fig. 4.

Figs. 3 and 4. — Prot sleeper. Detail of attachement by bolts.

Standard rail, 46 kgr. (90.7 lb. per yard.

Explanation of French terms:

Bois ou fibre = Wood or fibre. — Plaque Reiss = Reiss plate. — Semelle isolante = Insulating sole plate..

in position. The two nuts and the elastic plate are introduced into the cavity and placed on suitable tools, and the bolts are then inserted through the upper part like ordinary coach screws.

This system of attachment enables the clip or the coach screw to be used indifferently. If preferred, the Reiss plate may be replaced by a simple plate of metal, wood, fibre or bakelised paper, and any system of lock nut may be adopted.

The Prot sleeper also allows the old method of using wooden wedges for fixing the rails to be adopted again with exceptional convenience. The wedge is placed in position, and changed if necessary, with the greatest ease by way of the cavity without having to remove the sleeper from the track. As in the all-metal attachment, we again have a member holding the rail to the sleeper and pulled downward from above (the coach screw), and a member bearing against the sleeper from below and pulled upward. This last member, the wooden wedge, at the same time forms the elastic member and keeps the entire arrangement permanently tight. This method of attachment is less expensive than the all-metal attachment and may be used in its place in every case; although it may be considered as being less reliable and less perfect in the case of the flanged rail, it may be recommended for fixing chairs, in which case there is no risk of the coach screw tilting over as in the flanged rail. Some foreign railways, who prefer to retain the use of spikes for special reasons, have asked us for the wooden wedge.

It should be noted that the wooden wedge, which moreover is specially treated with tar beforehand, is amost entirely protected from the influence of damp and weather, an essential condition for its preservation and for maintaining the tightness of the fixture.

In order to preserve the smoothness of running, due to the elasticity of the wood beneath the rail flange, the sole plate interposed between the rail and the concrete is not one of a few tenths of an inch, but it is one of creosoted oak, bakelised poplar or vulcanised fibre of an average thickness of 15 mm. (5/8 inch). The sleeper is purposely provided with a suitable recess in which the sole plate is accommodated. *There is thus no risk of the sole plate turning or slipping, nor is it exposed to the weather except on a very insignificant surface.*

The special form of spike ensures correct tightening independently of the thickness of the sole plate between the rail and the sleeper, and also holds the rail in an absolutely fixed position.

d) *Electrical insulation.* — It is well known that most ferro-concrete sleepers have been found to be poorer insulators than timber sleepers, a serious disadvantage for railways using track circuit signalling systems.

The rail attachment of the Prot sleeper, being independent of the sleeper and having no metal parts buried in the concrete, provides a much more satisfactory insulation, approaching that of the timber sleeper. By tarring the attachment and the sleeper in its vicinity, a simple and not very expensive process, the resulting insulation is equal to, if not superior than, that of timber sleepers. The first tests have given resistances of the order of 3 000 ω per sleeper under heavy rain.

e) *Weight.* — As regards weight, there can be no question of a comparison between the Prot sleeper and the timber sleeper or even the ordinary ferro-concrete sleeper, which do not perform the same duty, since in the case of the Prot

Figs. 5 to 7. — Prot sleeper. —

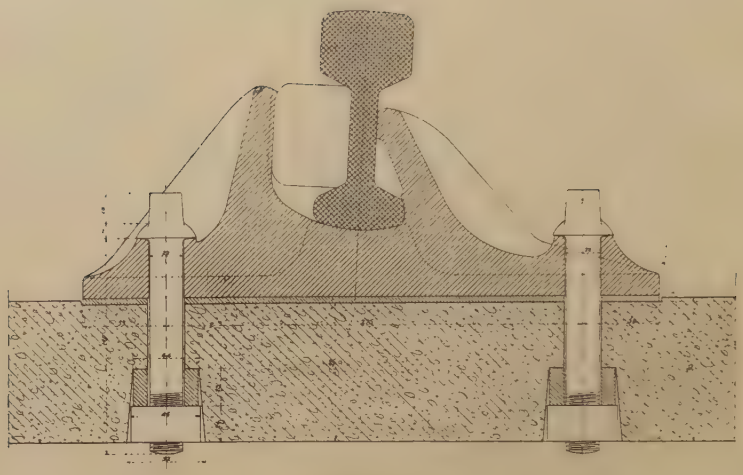

Fig. 5.

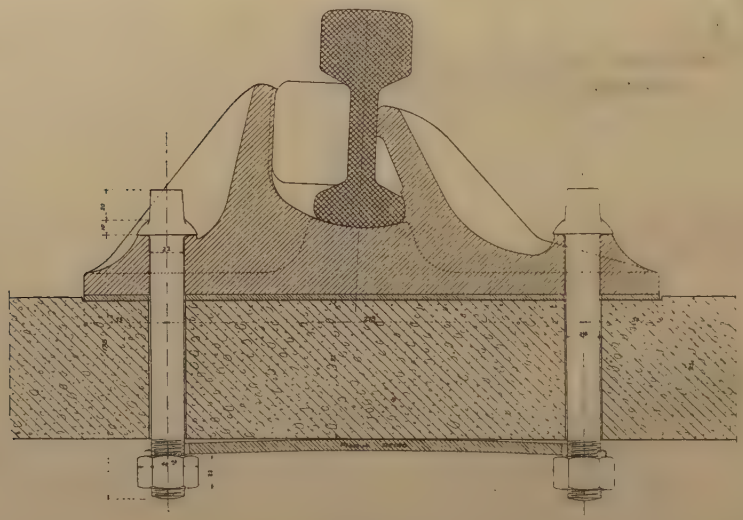

Fig. 6.

sleeper, as we have seen, the ballast is in a way incorporated in the sleeper.

Nevertheless, owing to its cavity and its well designed and rational shape, in which the material is better utilised than in the solid shapes generally adopted hitherto, the Prot sleeper, despite the fact that it possesses an incomparably greater bearing surface, does not weigh more as a whole (about 350 kgr. = 770 lb.) and

chment for a double headed rail.

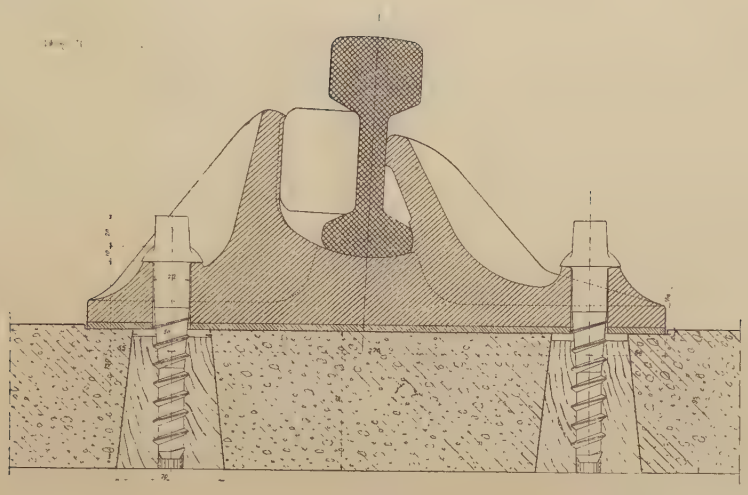

Fig. 7.

requires no greater weight of fittings, or even less, than most of the prism shaped sleepers at present on trial.

Moreover, although the lightness of the timber sleeper may be of advantage in placing the sleeper in position, a rare occurrence, no one will deny nowadays that the weight of ferro-concrete sleepers is a very valuable advantage as regards the stability of the track. The desire to persist in drawing a narrow comparison between the ferro-concrete sleeper and the timber sleeper, especially as regards weight, has certainly been an error and a result of too slow an evolution; the ferro-concrete sleeper must be heavier and we may believe that a more complete evolution will accept heavier and heavier sleepers.

f) *Handling.* — Again owing to its cavity the Prot sleeper is particularly easy to handle. For loading and unloading, it may readily be grasped by two hooks engaging in the ends of the cavity. For laying and adjusting the sleeper, it is easily moved by engaging a crowbar in each end or by passing a piece of timber through it from end to end.

g) *Upkeep.* — A track equipped with the Prot sleeper has a very satisfactory appearance, it is easy to travel over and inspect, and is easy to keep in a perfectly clean and well-conditioned state.

It follows from what was said earlier that the Prot sleeper practically ought not to settle. If the movements of the floor make it necessary, the track may be adjusted very easily by packing up the sleeper. If the subsidence is not very great, it may be done much more easily by using wooden sole plates of slightly different thicknesses, varying for example from 10 mm. to 20 mm. (15 mm. ± 5 mm.) [3/8 to 3/4 inch (19/32 ± 3/16 inch)], and which are very convenient to use owing to the special shape of the clips.

The attachment should not require practically any upkeep.

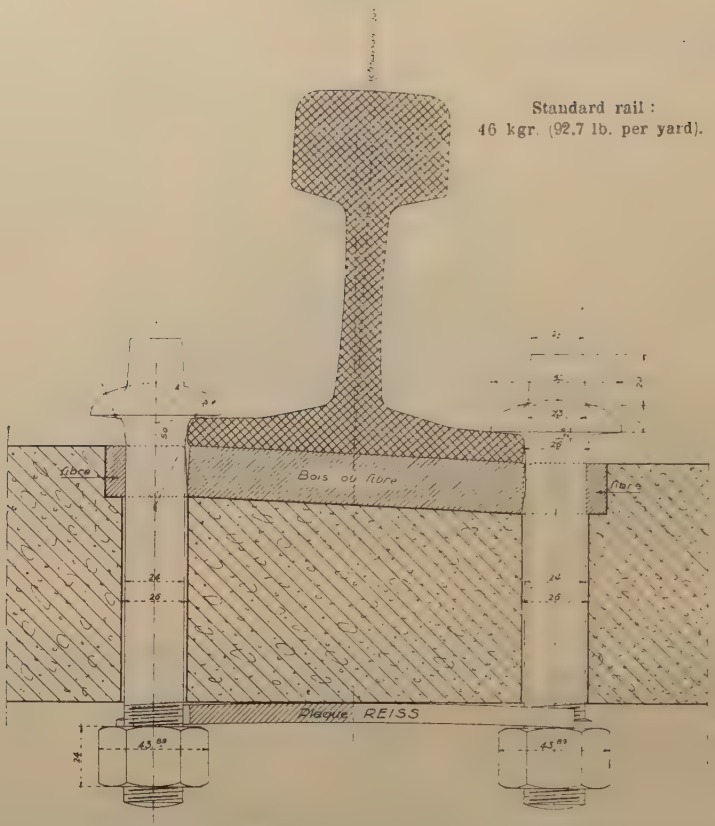

Fig. 8. — Prot sleeper. Detail of attachment by coach screw.

Explanation of German terms:
Bois eu fibre = Wood or fibre. — Inclinaison = Inclination. — Plaque Reiss = Reiss plate.

h) ***Price.*** — Here again, the origin of the comparison often made between the purchase price of the timber sleeper and that of the ferro-concrete sleeper is to be found in an excessive regard for the past and too slow an evolution.

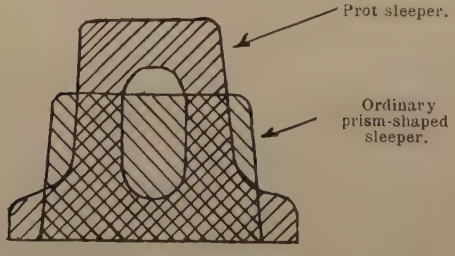

Fig. 9.

This comparison is no more justified than would be justified a narrow comparison between the price of a timber bridge and that of a ferro-concrete bridge. It is obvious that the comparison should cover more than the purchase price, otherwise it would be arbitrary and false, and should cover the total cost price, that is to say, in reality the comparison should include the interest on depreciation and upkeep expenses.

Provided a ferro-concrete sleeper is well designed (1), it should have a longer life than the timber sleeper, thus justifying a higher purchase price, and it should also enable considerable economies to be effected in maintenance costs.

The Prot sleepers as constructed at present weigh about 350 kgr. (770 lb.) and comprise 18 to 22 kgr. (39.7 to 48.5 lb.) of fittings. Taking the same basic prices for cement and steel, and the same general expenses, the cost price is therefore comparable with, if not lower than, that of the prism shaped sleepers at present in use, some of which, employed in large numbers, and consequently considered to be of an acceptable price, weigh up to 350 kg. (770 lb.) and comprise up to 25 kgr. (53 lb.) of fittings.

The objection might be made that, given an equal weight of ferro-concrete and steel, the Prot sleeper will be a little dearer than most of the sleepers used heretofore on account of its more carefully designed shape requiring more expensive moulds and also a little more labour. This consideration is true as regards the manufacture of small quantities, but it disappears when the manufacture of considerable batches of sleepers is involved, as would be the case normally. It should also be mentioned that the mould (shell and core) is not so complicated as one might think, and that the preparation of the rail attachment — two simple holes — is substantially simpler and less expensive than it is in almost all the other types at present known.

On the other hand, account should be taken of the considerable saving to be effected on ballast. Retaining the same under layer, and taking as a basis the simple replacement of the broken stone by the gravel filling the space between the Prot sleepers, the saving obtained is of the order of 15 to 25 francs per sleeper. In this way, a *first cost* is obtained which is comparable with or even lower than that of the cheaper ferro-concrete sleepers, and at the present time in the neighbourhood of that of timber sleepers. The saving on ballast effected in this way would be still greater if the custom, to which some railways propose to give a trial, of partly dispensing with the filling between the sleepers came into use.

Even though, for various reasons, chiefly in order to have a surface in better condition, it is desired to retain a slight layer of broken stone; this layer in any case may be reduced to about 5 cm. (2 inches) which would result in a saving of 5/6 on the cost corresponding to the ordinary layer of 30 cm. (12 inches).

As was pointed out previously, the condition of the floor and the distribution of the pressures may be improved still further by placing a thickness of ballast underneath the sleeper as may be considered useful, *but the Prot sleeper in itself will always be equivalent to 15 cm. (6 inches) of ballast under an ordinary sleeper, and other things being equal, it will always enable these 15 cm. of ballast to be saved.*

Finally, if preferred, a half-way solution may be adopted, a little more ballast being retained and the width of the sleeper being in this case reduced, resulting in a lighter and less costly sleeper.

The choice of the solution will merely depend upon the special conditions of the line which is to be equipped. In this connection it is of interest to emphasize once again how much the Prot sleeper

(1) It is necessary to lay stress on this point : the fatigue of the steel and particularly of the ferro-concrete must be low enough to enable the sleeper to resist very frequently repeated stresses for a considerable time.

adapts itself with flexibility to the most varied conditions.

The advantage of the Prot sleepers as regards the fatigue of the rails, which was mentioned earlier on, enables the sleepers to be placed closer together than timber sleepers, or sleepers of similar dimensions, other conditions being the same. This again is a consideration, the economic interest of which cannot be overlooked as regards both first cost and upkeep.

If in addition it is considered that this sleeper, working in favourable conditions, without apparent fittings, and provided with a rail attachment which is easily and entirely replaceable, ought to have a longer life than those of all the known types, and if we add that it eliminites any necessity for re-tightening or re-tamping, it will be seen that its upkeep and depreciation are extremely small and lower than those of all the sleepers which have been used or tried hitherto.

SUMMARY.

Mr. Freeman, Chief Engineer of the New York Central Railroad, in the very full report which he has drawn up for the Madrid Congress and which has already been referred to, points out that, in order to give satisfactory results, a ferro-concrete sleeper should satisfy the following conditions :

1. Sufficient strength to withstand the shock and vibration of heavy traffic;

2. A satisfactory fastening for the rail or chair; one that does not require too much attention and is simple and easy in its adjustments. Provision must be made so that shimming between rail and tie can be readily accomplished;

3. Where track circuits are used, adequate and reasonably permanent insulation must be provided between the rail and the tie to insure positive operation of signal system at all times and under varied weather conditions;

4. A roughened surface in contact with the ballast to overcome the lessened frictional resistance of concrete as compared to wood;

5. Provision for anti-creepers properly insulated to prevent leakage of electric current where track circuits are used and at the same time applied so as not to cause the tie to roll;

6. A life equivalent or commensurate to that of treated wooden ties to justify use of concrete ties from an economic standpoint. In other words, if the concrete cross-tie costs twice as much as the treated wooden cross-tie, it should have a life approximately twice the life of the wooden cross-tie.

It is interesting to note, by way of summarising what has gone before, how much the Prot sleeper appears to answer in a remarkable manner to these various demands.

1. If ferro-concrete sleepers, subjected as they are to frequently repeated stresses and shocks, are to have a long life, it is essential that their different parts should only work at a relatively low fatigue ratio. As pointed out previously, and as shown in detail in the mathematical note to follow, the Prot sleeper by virtue of its entirely new design is in excellent conditions of stability and mechanical resistance, much superior than those obtained in the case of most of the types which have been tried hitherto. More particularly as regards shocks, the use of a thick sole plate under the rail flange and the maintenance of a powerful tightening of the rail attachment by means of the elastic plate appear as serious guarantees of long life.

The shapes and the dimensions of the

ferro-concrete, as well as those of the fittings have been designed to limit the stresses to very reduced proportions, also an excellent guarantee for the life of the sleeper.

2. The rail attachment of the Prot sleeper, by its robustness and simplicity, well satisfies the conditions indicated by Mr. Freeman. All the modifications, whether they employ the coach screw or the rail spike, enable wooden or fibre sole plates of a variable thickness to be used and provide the desirable facility of adjustment.

3. The electrical insulation is obtained in conditions similar to those provided by the timber sleeper.

4. The rough surface required by Mr. Freeman is provided in a very effective manner by the ribs on the underneath face of the sleeper.

5. As regards creep, the powerful and permanent manner in which the rail attachment is tightened would appear to be a guarantee of solidity between the rail and the sleeper. On the other hand, the rigidity of the sleepers relatively to the ground appears to be obvious, especially if the spaces between the sleepers are completely filled in.

6. Finally, the Prot sleeper appears to be satisfactory from the economic standpoint in more than one respect. Its relatively low first cost price and its very long life bring its depreciation to a figure which is certainly lower than that of the timber sleeper. Its particularly durable resistance to sinking and tightening of the rail attachment would appear to reduce maintenance almost to nothing, a very important consideration in the cases, which are nowadays frequent, when labour is scarce.

Conclusion.

In conclusion, it is possible to believe that the Prot sleeper while giving to the track an excellent behaviour, will be in addition a really economic sleeper. It appears to be the logical outcome of an evolution which, departing from the servile imitation of the timber sleeper, must of necessity know some hesitation and overcome some rule-of-thumb ideas before arriving at the final adoption and utilisation of ferro-concrete in the modern railway.

Instructions for laying the Prot sleeper and for its maintenance.

General considerations.

Prot sleepers are essentially different in their conception from ordinary sleepers and should not be laid on the same principles.

Ordinary sleepers, as far as possible, should rest on the ballast only in the portion of their length which is near the rails, and should be tamped in that portion only. They are not tamped in the middle as a matter of principle, unless it is intended that they should sink systematically, as is the case with some ferro-concrete sleepers. When laying ordinary sleepers, no attempt is made to level the ballast very carefully, the rail being levelled subsequently by tamping.

The Prot sleeper, on the contrary, should rest on the ballast along the whole of its lower face. If the whole of its bearing surface is not utilised, or if it is « tamped » in the neighbourhood of the rail, it will not be working in the conditions for which it has been designed.

The Prot sleeper should not be tamped. Tamping, or the corrective or preventive measure of allowing the sleeper to sink,

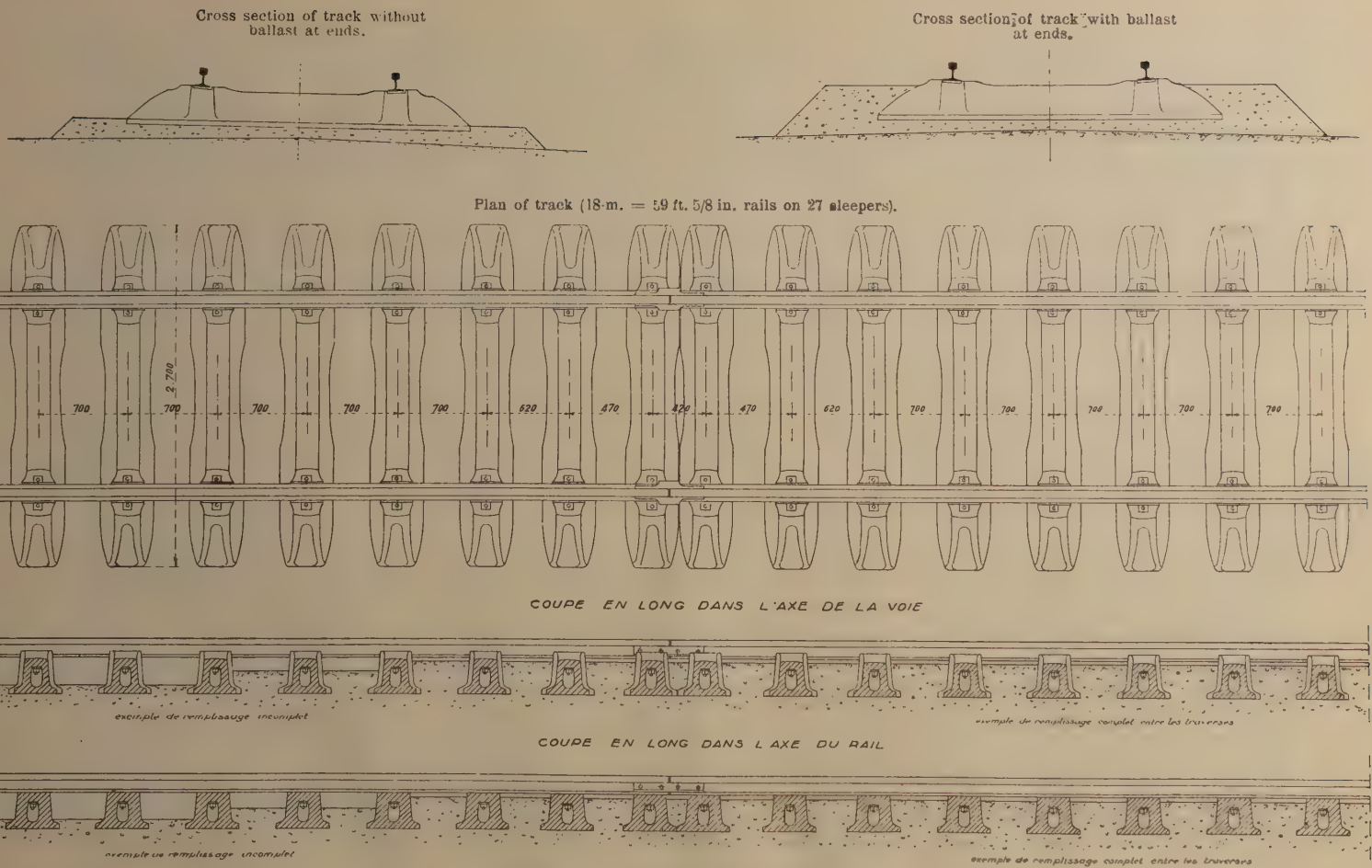
Cross section of track without ballast at ends.
Cross section of track with ballast at ends.
Plan of track (18 m. = 59 ft. 5/8 in. rails on 27 sleepers).
2 700
700
620
470
COUPE EN LONG DANS L'AXE DE LA VOIE
exemple de remplissage incomplet
exemple de remplissage complet entre les traverses
COUPE EN LONG DANS L'AXE DU RAIL
exemple de remplissage incomplet
exemple de remplissage complet entre les traverses

Fig. 10. — Prot ferro-concrete sleeper.

Explanation of French terms:

Coupe en long dans l'axe de la voie = Longitudinal section along the track axis. — Coupe en long dans l'axe du rail = Longitudinal section along the rail axis. — Exemple de remplissage incomplet = Example of incomplete filling. — Exemple de remplissage complet entre les traverses = Example of complete filling between the sleepers.

should not be used, for the Prot sleeper ought not to sink (1).

Laying. — First of all, before placing the sleeper in position it is necessary to obtain a ballast surface which is as flat and as level as possible, the sleeper being afterwards simply placed on this surface without any tamping. After the traffic has run over them at speed for a few days, the track will be adjusted as described below in connection with maintenance.

Maintenance. — To adjust the track, proceed in the following manner: Loosen freely the attachments so that the sleeper rests freely on the ballast and cannot in any case be held « in the air » by the rail. Level the sides of the sleepers resting thus at each end.

If the sleeper has subsided by a few millimetres only, replace the sole plates by thicker sole plates, so that at each end of the sleeper the rail is provided with support on the desired side. If the sleeper has subsided too much, or if the sole plates already placed in position are in the neighbourhood of the maximum thickness, lift the sleeper freely, pack it underneath by 10 mm. (3/8 inch) and replace it in position with sole plates in the neighbourhood of the minimum thickness.

In this way, all the advantages of packing are obtained, that is to say, the retention of a stable and well packed layer beneath the sleeper which tamping has the disadvantage of destroying. It is only necessary to raise the sleeper by packing on rare occasions and by important amounts; when a slight raising of the sleeper is required, it is preferable to do this by changing the sole plate, an operation which is simpler and attended by more definite results.

Ballast. — The sleepers are placed on a fine ballast of sand, gravel, etc., and if it is necessary to obtain a very carefully conditioned surface, broken stone of a size of 4 cm. (1 9/16 inches) may even be used. It is without interest and clearly disadvantageous to lay ferro-concrete sleepers on coarser ballast than this.

The thickness of the ballast (top layer and bottom layer) ought to depend upon the nature of the floor.

On a platform of good ground, well conditioned and well made, the sleepers may even be placed directly on the ground, the « tamping » layer not being required, and the bearing surface provided by the sleeper being sufficient, as explained elsewhere.

On clayey floors it is necessary, in order to obtain stability of the track, to place under the sleeper a sufficient bed of cinders, sand, gravel, etc., so as to obtain sufficient distribution of pressure and allow the water to drain readily.

(1) Or more exactly, should only sink by a quite negligible amount.

Note on the calculation of ferro-concrete sleepers.

Without investing the calculation with more importance than it deserves in such a matter, it is not without interest to try to take into account the order of magnitude which the factor of safety of a ferro-concrete sleeper may attain, and to try to analyse the conditions under which it works.

It is certain that the sleepers should not break.

It should also not be forgotten, however, that a sleeper is essentially a mass-production article, the cost of which is basic, and that a high factor of safety is an expensive luxury. Moreover, the accidental cracking of a sleeper is by no means a catastrophe, and if the fact is still a somewhat rare occurrence, it may be less expensive than larger dimensions. Although the fracture of a rail is incomparably more dangerous than the cracking of a sleeper, the types of rails in use are adhered to, and no attempt is made to obtain a greater factor of safety by an increase in the section, the cost of which would be such as to render the working unprofitable.

It is merely necessary, therefore, apart from fairly rare cases, that the fittings of a ferro-concrete sleeper shall not have to support at any point stresses greater than their limit of elasticity, which would involve not the fracture of the sleeper but a least the cracking or fissuring of the concrete.

Experiment alone is able to supply a final answer to this question, but it is expensive and long in addition. It does not tell us whether a sleeper which holds is simply sufficient or is excessively strong, and by itself it will not provide a result except after numerous attempts in the dark.

Aided by experiments already made, calculation is able to provide indications, the exactness of which must not be overestimated but which are not without some value.

Loads to be assumed.

1. *Maximum regulation loads.*

The first question which arises in the calculation of a sleeper is the determination of the maximum loads to be considered.

The maximum weight of the axles allowed by the French Regulation is 20 t. (19.7 Engl. tons) and the minimum gauge is 1.50 m. (4 ft. 11 in.). It may be asked whether a sleeper, the life of which on principle must be long, is not exposed to an increase of this maximum load a few years hence, for the maximum of 20 t. has been practically reached at the present time and when the actual Regulations were drawn up, the figure of 22 t. (21.65 Engl. tons) had already been considered.

This is a special question, and we will adhere to the figure of 20 t., it being understood that, on certain large railways a higher figure may be assumed in order to make ample provision for the future, just as in the same way a lower figure may be assumed for lines of small traffic. It would scarcely be justified and certainly not economical to have a single type of sleeper for all lines and for all traffic.

2. *Out-of-balance of the axles.*

A defective state of the rolling stock may result in the axles, some of which will thus weigh more than 20 t. (19.7

Engl. tons), being out balance. This out-of-balance, however, rarely attains a considerable importance, and if the increase to be made on this account is estimated at 2 t. (1.97 Engl. tons) say 10 %, we shall only have disregarded accidental occurrences of a very exceptional nature.

3. *Tilt or cant.*

It may happen also that one wheel is loaded more than the other wheel of the same axle. This is particularly a regular occurrence in curves, when the two lines of rails are only loaded equally for a definite speed. An elementary calculation shows that the increase due to this fact may attain 15 %.

4. *Solidarity of the sleepers.*

On the other hand, it must be borne in mind that this weight is not carried by one sleeper alone. Even if the axle is exactly vertically above a sleeper, a portion of the load is transmitted to the neighbouring sleepers.

We shall attempt to determine this distribution.

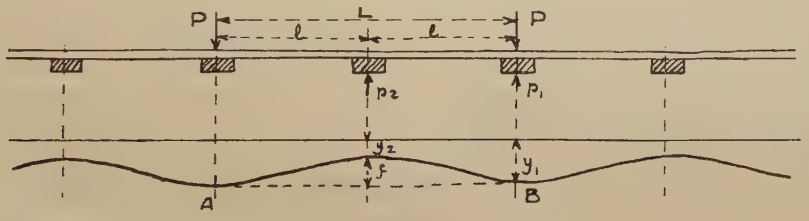

Fig. 1.

In the first place, let it be supposed that the arrangement of loads shown above is obtained.

Let p_1 be the reaction of the ground on the loaded sleeper, y_1 the distance which the ground is depressed, which distance as a first approximation we shall suppose to be uniform under the sleeper (1), and p_2, y_2, the similar quantities corresponding to the neighbouring sleeper.

If we assume that the reaction of the ground is proportional to the depression, we shall have :

$$p_1 = \mathrm{K}y_1$$
$$p_2 = \mathrm{K}y_2$$
$$p_1 + p_2 = \mathrm{P}$$
$$\mathrm{K} = k\mathrm{S}$$

where k is the coefficient of elasticity of the ground, S is the bearing surface of the half sleeper, and P is the weight of one wheel.

The portion AB of the rail may be considered as a beam supported at both ends and loaded in the centre with the load p_2, whence, by a well known formula, we have :

$$f = y_1 - y_2 = \frac{p_2 \mathrm{L}^3}{192\mathrm{EI}} = \frac{p_2 l^3}{24\mathrm{EI}}$$

E being the coefficient of elasticity of the rail, I its moment of inertia and l the distance between the sleepers. We get :

$$p_1 - p_2 = \mathrm{K}p_2 \frac{l^3}{24\mathrm{EI}}$$

$$p_2 = \mathrm{P}\,\frac{1}{2 + \frac{\mathrm{K}l^3}{24\mathrm{EI}}}.$$

It will be seen that p_2 increases and

(1) This hypothesis is unfavourable, the actual depressions under the rail being larger than those that would correspond to a uniform sinking of the sleeper.

approaches $\frac{P}{2}$ as K becomes smaller, as the sleepers are closer together and as the rail becomes more rigid, which is quite obvious.

Let us see what is the order of magnitude of the correction term $\frac{Kl^3}{24EI}$. Taking the kilogramme and the centimetre as units, let us assume that :

$k = 4$ $\qquad$ $k = 10$ extreme values.

$S = 20 \times 70 = 1\,400$ $\qquad$ $S = 45 \times 140 = 6\,300$ extreme values,

$l = 75$

$E = 2\,000\,000$

$I = 1\,620$ [46 kgr. (92.7 lb. per yard) stand.] $\qquad$ $I = 1\,009$ [36 kgr (72 6 lb. per yard) stand.]

minimum $\frac{4 \times 1\,400 \times 75^3}{24 \times 2\,000\,000 \times 1\,620} = 0.03$ $\qquad$ $p_2 = P\frac{1}{2\,03} =$ about 0.5 P,

maximum $\frac{10 \times 6\,300 \times 75^3}{24 \times 2\,000\,000 \times 1\,009} = 0\,52$ $\qquad$ $p_2 = P\frac{1}{2.52} =$ about 0.6 P.

If the arrangement of loads shown below is considered, a calculation similar to, but more complicated than, that given above shows that in the most favourable cases the sleeper hardly carries more than 1/3 of the load vertically

Fig. 2.

above it, but that on the contrary, in unfavourable cases it may be relieved of only about 1/4 of this load.

An extreme assumption is that which consists in considering the rail in the portion concerned as a beam having its ends free at A and B.

Using the notation given in the figure, we have :

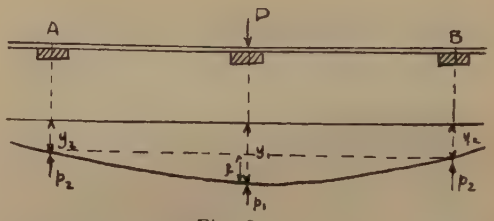

Fig. 3.

$$p_1 + 2p_2 = P$$
$$p_1 = Ky_1$$
$$p_2 = Ky_2$$
$$f = y_1 - y_2 = (P - p_1)\frac{l^3}{6EI}$$

Whence :

$$p_2 = P\frac{1}{3 + \frac{Kl^3}{3EI}}$$

In favourable cases : rigid rail, deformable ground, small distance between the sleepers, the load is distributed almost evenly between the three sleepers, while in the numerically unfavourable case considered above, we have practically :

$$p_2 = \frac{P}{8}$$

that is to say, the sleeper carries about 3/4 of the load vertically above it.

It should be noted, moreover, that the rails are generally more rigid as the loads are heavier and the traffic more intense, so that the most unfavourable conditions are not obtained.

It may be assumed therefore that the

load actually carried by the sleeper is generally less than 3/4 of the maximum axle weight to be considered. Reverting to the assumptions made above, we should thus have :

10 t. (1 + 0.10 + 0.85). 0.7 = about 9 t. (8.86 Engl. tons).

We have also to consider, however, that the sleepers are not always levelled in a very perfect manner, and that irregular subsidence of the ground may be produced and appreciably modify the assumptions on which the preceding calculation is based. Also, in order only to eliminate sufficiently rare cases, it would appear prudent to assume that the maximum effort transmitted by the wheel of a 20-t. axle may be 10 t.

Conditions will obviously be better if the track is kept in good repair, and if the ground is good and, on the contrary, they will be more uncertain if the track is badly adjusted and the ground is unstable. Conditions will also be better for the sleepers if the rails are rigid and the sleepers are close together.

5. *Shocks.*

In a length of the rail, there are as a matter of principle, no shocks but only rapidly varying stresses. In the presence of stresses of this type, the deformations, which only assume their equilibrium value at the end of a finite interval of time, have not the time to assume this value and the material possesses an apparent coefficient of elasticity greater than its true coefficient of elasticity. This is a phenomenon which scarcely lends itself to mathematical treatment, but which should not apparently be unfavourable to the sleeper, an increase in the rigidity of the rail tending to reduce the loads which it transmits, and an increase in the rigidity of the ground being on the whole rather favourable to the sleeper.

There may be a veritable shock in the case where the wheel has a flattened portion. This is an occurrence to which is due always a rather large number of fractured rails. Moreover, it is fairly rare and it does not appear necessary to provide for this contingency systematically.

At the joint, on the contrary, shocks are produced systematically, but it should be noted that they are only produced when the axle is not over a sleeper, unless the joint is supported. If the sleepers adjacent to the joint are closer together, the shock may be greater but the distribution of pressure is also better. The most unfavourable arrangement is that in which the facing rail is supported by the sleeper very close to the end of the rail.

The use of a thick sole plate, keeping the attachment well tightened up and tamping of the sleeper should obviate all unfortunate consequences of shock at the joint.

Moreover, if the joint should actually fatigue the sleepers near it, it would be better to study the improvement of the joint rather than make all the sleepers of dimensions which would only be necessary for a small number of them.

6. *Dynamic effects.*

An increase in the vertical stresses is also caused by the reciprocating parts of the engines and the rolling and lurching of the engines. Their calculation is difficult, but as far as may be judged, this increase would appear to be considerable, and is undoubtedly one of the causes which necessitates the adoption of a considerable factor of safety, even after careful calculation.

Calculation of a sleeper.

The essential factor to be borne in mind in connection with the calculation of a sleeper, is that the ground on which it rests is deformable. The ground, under

the effect of the pressures transmitted to it by the sleeper, deforms elastically up to a certain value of the pressure, and permanently beyond that value.

We shall consider first af all what takes places in the elastic period.

a) *Elastic period.*

It is generally assumed that in this period the reaction of the ground is a linear function of the depression. The deformation of the sleeper is then given by the equation of the 4th order :

$$\frac{d^4y}{dx^4} = -ky$$

the solution of which is of the form :

$$y = l^{\alpha x}(A \cos \alpha x + B \sin \alpha x) + l^{\alpha x}(C \cos \alpha x + D \sin \alpha x)$$

The calculations are most tedious and lead to rather clumsy formulæ.

The problem has been attacked in a general manner by several writers and was taken up again recently as regards the calculation of ferro-concrete sleepers by Mr. Dino Levi de Veali in a very remarkable paper published in the February 1929 number of the *Bulletin of the International Railway Congress Association.*

Since, however, the accuracy to which claim be laid is not very great for reasons which will be understood and which will be referred to later, we prefer more particularly to employ in place of the analytical method a graphical method of false position, the use of which is obviously not very accurate but which is less tedious, however, and possesses the avantage that it provides at once deformation curves. By way of indication merely, the full analytical solution of two special cases is given in the appendix.

Plate I below shows the bending moments and the deformation curves of a sleeper laid on an elastic ground. The numerical data correspond to the ordinary timber sleeper 2.40 m. (7 ft. 10 1/2 in.) long and 0.24 m. (9 7/16 inches) wide.

The first two figures correspond to the even distribution of the reactions of the ground, that is to say on an infinitely soft ground. The curve of the moments would be the same, and the deformation curve would have the same shape on almost the same scale for an extremely rigid sleeper resting on any ground whatsoever.

The other figures correspond to the case of ground having a coefficient of elasticity of 4 kgr. cm./cm² or of 10 kgr. cm./cm², extreme cases in practice according to Mr. de Veali.

It will be seen that the harder the ground (or what amounts to the same thing, the more flexible the sleeper) the greater the deviation of the results from those which would correspond to an even distribution of the reactions of the ground, itself corresponding to a sleeper of very great rigidity or to very deformable ground.

It will also be seen that for a timber sleeper 2.40 m. (7 ft. 10 1/2 in.) long, the bending moment opposite the rail is a little greater than that which would correspond to a more rigid sleeper, but that, on the contrary, it is appreciably lower in the centre of the sleeper.

These results may be expressed as a function of the length of the sleeper by the curves shown below (fig. 4), where the form of the curves of Mr. de Veali will be seen again. If extended to the right, these curves would allow of a horizontal tangent corresponding to the critical length, and would be continued beyond by a horizontal line. The more rigid the sleeper, or the more deformable the ground, the nearer is the curve corresponding to even distribution ap-

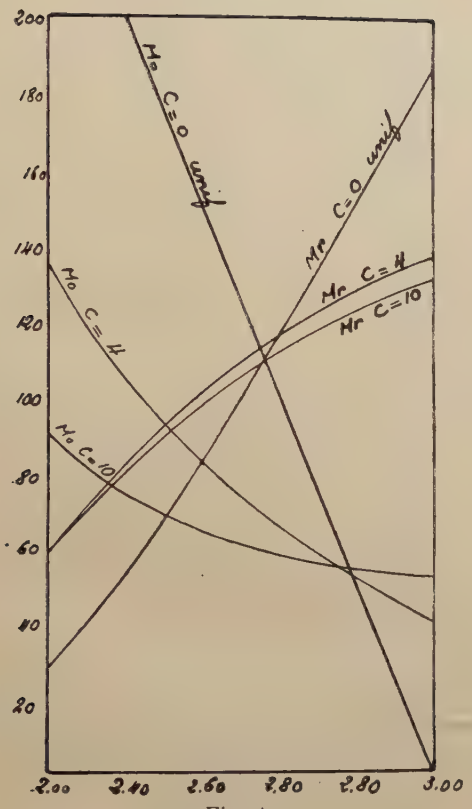

Fig. 4.

Abscissa : Length of sleeper.
Ordinate : Moments in kilogrammetres for 1 t. per wheel.
Mr = Moment opposite the rail.
Mo = Moment in the centre.

proached. This result is translated in the calculations by the form of the term:

$$\alpha = \sqrt[4]{\frac{k}{4EI}}$$

which is introduced at the commencement of integration (see the appended notes).

b) *Period of permanent deformations.*

We shall not lay any more stress on the results relating to the elastic period, which only have the value of an indication.

The period of elastic deformations is in fact limited to a fairly short period after the sleeper has been laid.

The ground is a pulverulent mass, passing alternately through states of dryness and moistness, and subjected in addition to vibrations. The ground receives pressures of several kilogrammes per cm² repeated a very large number of times and transmitted by the sleepers. It would appear quite inevitable that this ground will ultimately be deformed more in the zones of more intense pressure and less in the zones of less intense pressure.

This is a fact of experience : the sleepers « sink » at their ends and rise in the centre. This is an important fact which must be insisted upon in the calculation of sleepers and it is so true that the ordinary prism-shaped ferro-concrete sleepers, which ought to « hold » according to calculations relating to the elastic period, do not in fact hold, and crack at the end of a certain length of time after they have been placed in position, unless the precaution is taken to remove the tamping in the middle.

The question is therefore of paramount importance, and deserves a detailed study. In a treatise on construction, we find the following resistances admitted for different kinds of grounds, or if preferred, the pressures on these grounds which ought not to be exceeded in practice :

1. Mud and soft clay, $<$ 0.50 kgr. (7.1 lb. per sq. inch).

2. Open earth, sandy clay, 2 to 3 kgr. (28.4 to 42.6 lb. per sq. inch).

3. Sand and old gravel, compact clay, 3 to 6 kgr. (42.6 to 85.2 lb. per sq. inch).

4. Resistant ground, $>$ 6 kgr. (85.2 lb. per sq. inch).

These are merely orders of magnitude, the resistance of ground depending chiefly upon its state of moistness, and they are also figures which apply only to static and permanent pressures (foun-

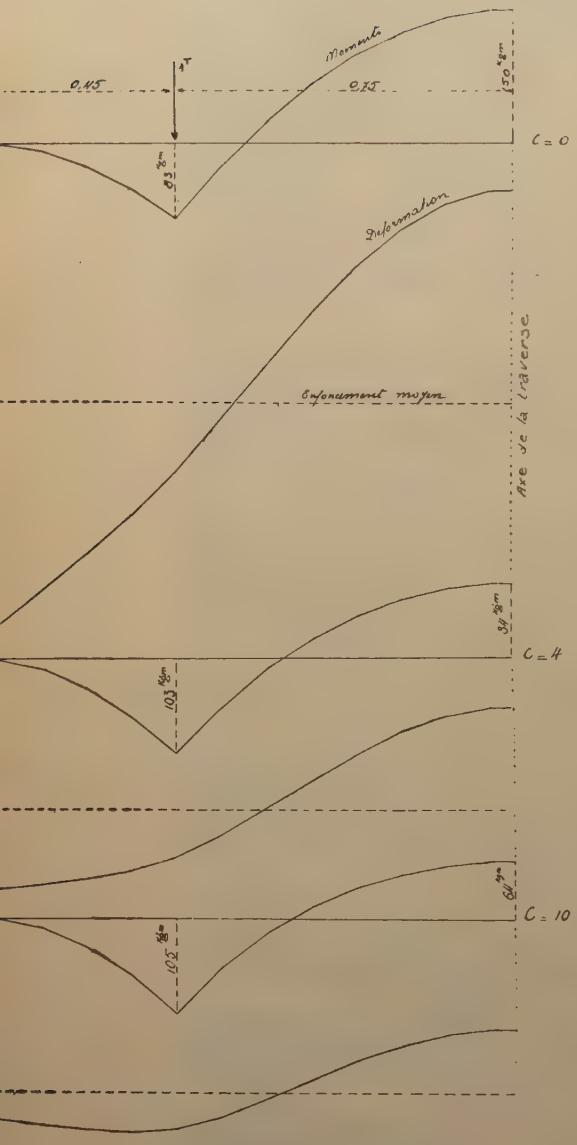

Plate I.

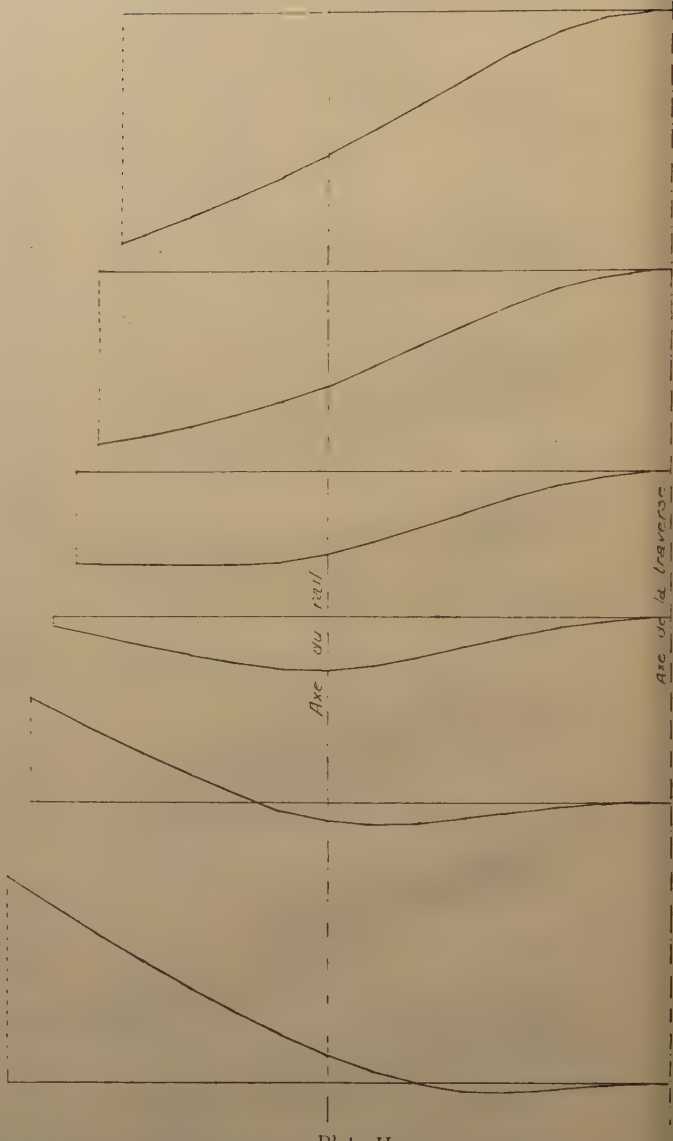

Plate II.

***Explanation** of German terms:* Axe de la traverse = Axis of the sleeper. — Enfoncement moyen = Mean depression. —Axe du rail = Rail axis.

dations) and which are obviously too high for repeated stresses.

A sleeper 0.24 m. (9 7/16 inches) wide, tamped for 0.35 m. (1 ft. 1 3/4 in.) on each side of the rail axis, and loaded with 17 t. (16.7 Engl. tons) transmits through its lower face to the ground a mean pressure of 5 kgr. per cm^2 (71.1 lb. per sq. inch); a sleeper 0.30 m. (11 13/16 inches) wide and 2.40 m. (7 ft. 10 1/2 in.) long, even if it rests on the ground over the whole of its surface, still transmits mean pressures of nearly 3 kgr. (42.6 lb. per sq. inch) if it is loaded with 20 t. (19.7 Engl. tons).

When we consider that the problem concerns ground which may be soaked and washed by rain, and when we consider once again that frequently repeated stresses are involved, we find that, apart from very good kinds of ground, these mean pressures are of an order amply sufficient to bring about permanent deformation.

Moreover, the resistance, or more exactly the limit of elasticity of ground would appear to depend essentially upon the shape and the extent of the surface which it supports. It will be understood that an indefinite surface would produce in all cases practically elastic deformations alone, while a very small surface penetrates and produces a permanent deformation in a mass without cohesion, and in this respect, the bearing surface of a sleeper of ordinary dimensions is a very narrow surface.

Referring to the deformation curves of plate I, it will be seen that the sleeper 2.40 m. (7 ft. 10 1/2 in.) long, especially if it is not very rigid or if it is resting on ground which is not very deformable, will exert on the ground a very much greater pressure than the mean pressure near the ends, and less than this mean pressure near the centre. The sleeper will tend to settle or sink near the ends (fig. 5). The sleeper will not stop sinking until the reaction of the ground is uniform under the loaded sleeper, the deformation curve of which will then be similar to the profile of the ground (dotted line).

Fig. 5.

This would at least be the case if the pressures involved were static or slowly applied, but once the ground has been deformed, the sleeper comes « loose » when the load is no longer applied, and is caused to strike against the ground each time the load is applied, resulting in a « pile-driving » effect which tends to increase the sinking of the sleeper.

The reactions of the ground are no longer uniform, they become a maximum in the zones where, during the elastic period, they were a minimum.

A state of equilibrium may be set up, or rather a sort of ultimate state, the sleeper continuing to sink, partly due to its striking the ground, near its ends, and partly due to static pressure near its centre, at least until a sort of refusal is obtained, if such is possible.

During the whole of this period, however, there is deformation and fatigue of the sleeper, greater, at least in certain points [greater in the centre for the sleeper 2.40 m. (7 ft. 10 1/2 in.) long] than those corresponding to an even distribution of pressure, and greater *a fortiori* than those corresponding to the elastic period.

It is easy to see that, under these conditions, certain types of solid section, prism-shaped sleepers at present in use, despite a very great weight of fittings, contain steel loaded in the neighbourhood of its elastic limit, if not above it, which results in the cracking of the ferro-concrete.

As regards timber, there is no elastic limit to be taken into consideration, but only an ultimate strength. It is easy to see that under the same conditions, the

timber sleeper resists with a safety factor of the order of 2.

Timber is therefore adapted to the ordinary dimensions of sleepers, but ferro-concrete, a substantially different material, does not so adapt itself.

On the other hand, ferro-concrete possesses resources which timber does not possess, and which may be used in taking into account the indications of the study which has just been made (1).

The rational ferro-concrete sleeper.

It follows from what has gone before that, above all, it is essential to see that the sleeper does not settle or sink, as far as it is possible to do so.

The preceding study provides us with indications of several means :

1. Sinking of the sleeper, as we have seen, is a result of the inequality of the pressures exerted on the ground by the sleeper during the elastic period. A very rigid and thick sleeper, having a large moment of inertia is, in this respect, in more favourable conditions than a sleeper which is more deformable, the pressures transmitted to the ground by the sleeper being more even, the greater the rigidity of the sleeper.

2. If, on the other hand, we consider the deformation curves of sleepers of different lengths, assuming the reactions of the ground to be uniform, we see (plate II) that the length ordinarily admitted of 2.40 m. (7 ft. 10 1/2 in.) is a long way from being the most favourable and that a sleeper 2.70 m. (8 ft. 10 5/16 in.) long, other things being equal, provides a much more uniform distribution of the depression, a depth of depression smaller by 2/3 and consequently less tendency to settling or sinking of the sleeper.

3. This tendency to sinking will be reduced still further by increasing the bearing surface of the sleeper, in the first place because the mean pressure exerted on the ground will thus be reduced.

The initial conditions are rather heavier as regards the bending moment opposite the rail, but at the same time a guarantee is obtained that these conditions will not be aggravated subsequently and that they will still be more favourable than they would have been in the case of settling or sinking of the sleeper.

In addition, advantages are gained as regards both the behaviour of the track and the maintenance expenses, on which it is superfluous to insist.

Moreover, attention should be drawn to the fact that this increase in the bearing surface, involving less subsidence of the sleeper, is able to reduce considerably rail fatigue and the risk of fractures, the stresses developed in the rails by the passage of the axles being given by an expression in which the coefficient of compressibility of the ground is a denominator.

Conclusions.

It thus becomes possible to calculate with some semblance of certainty, the stresses to which our type of sleeper is subjected.

It may merely be added that, as we have seen, retaining the most unfavourable and the most prudent hypotheses, the dimensions of our sleeper have been fixed so that it will be able to resist siresses double those which have ultimately been arrived at, without the steel members exceeding their elastic limit.

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(1) It is curious to remark that, in his study, Mr. de Veali, has omitted, by assumption, sleepers wider than 0.30 m. (11 13/16 inches), thicker than 0.16 m. (6 5/16 inches) and hollow sleepers, which include just the type we are suggesting, and in this way has decided against prism-shaped sleepers.

No other conclusion could be arrived at from the standpoint adopted by Mr. de Veali, the only possible solution being thus eliminated *a priori*.

In fact, in order to allow for the dynamic stresses which we have discussed and which are difficult to calculate, to allow also for several defects in manufacture, always possible, and finally to allow for the inevitable inaccuracy of the hypotheses, it is necessary to have a safety factor of this order of magnitude.

This factor of safety is similar to that for a timber sleeper and as far as we know, is not reached by far by any other ferro-concrete sleeper of prismatic shape.

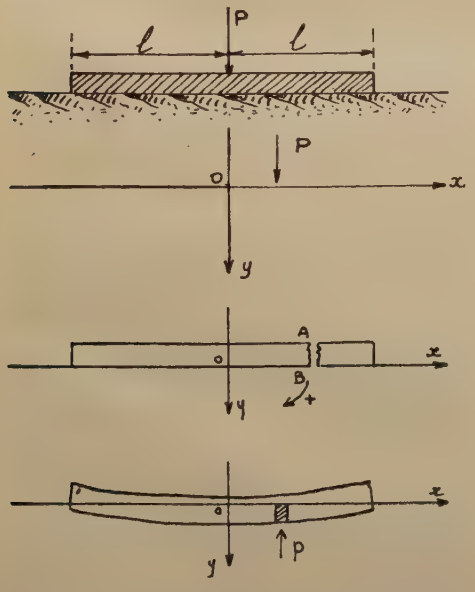
It has been possible to construct it economically, thanks to an entirely new and well-designed shape, and by making the best use of the material.

APPENDED NOTE.

A beam resting on an elastic ground.

Analytical theory.

Let a beam of length $2l$ be loaded in the centre by a weight P and rest on



ground the reaction of which is assumed to be proportional to the depression at the point considered.

Origin of the abscissæ at the centre of the beam, the position of the axes being as shown opposite, downward forces positive.

Shearing stress in the section AB = resultant of the forces applied to the length on the right of AB.

Bending moment AB = moment of the forces applied on the right of AB, positive direction shown in the figure.

Reaction of the ground on a length dx of the beam $= pdx$ with

$$p = -ky \qquad k \geq o$$

In these conditions, we have the known equations :

$$\frac{d^2y}{dx^2} = +\frac{\mathfrak{M}}{EI} \qquad \mathfrak{M} = EI\frac{d^2y}{dx^2}$$

$$\frac{d\mathfrak{M}}{dx} = -T = EI\frac{d^3y}{dx^3}$$

$$p = -\frac{dT}{dx} = -ky = EI\frac{d^4y}{dx^4}$$

The deformed fibre is therefore defined by the differential equation of the 4th order :

$$\frac{d^4y}{dx^4} = -\frac{k}{EI}y$$

The solution of this equation is of the form :

$$y = l^{\alpha x}[A \cos \alpha x + B \sin \alpha x] + l^{-\alpha x}[C \cos \alpha x + D \sin \alpha x]$$

And we have in fact :

$$\frac{dy}{dx} = \alpha[l^{\alpha x}(A \cos \alpha x + B \sin \alpha x - A \sin \alpha x + B \cos \alpha x) + l^{-\alpha x}(- C \cos \alpha x - D \sin \alpha x - C \sin \alpha x + D \cos \alpha x)]$$

$$\frac{d^2y}{dx^2} = \alpha^2[l^{\alpha x}(- 2A \sin \alpha x + 2B \cos \alpha x) + l^{-\alpha x}(2C \sin \alpha x - 2D \cos \alpha x)]$$

$$\frac{d^3y}{dx^3} = \alpha^3[l^{\alpha x}(- 2A \sin \alpha x + 2B \cos \alpha x - 2A \cos \alpha x - 2B \sin \alpha x) + l^{-\alpha x}(-2C \sin \alpha x + 2D \cos \alpha x + 2C \cos \alpha x + 2D \sin \alpha x)]$$

$$\frac{d^4y}{dx^4} = \alpha^4[l^{\alpha x}(- 4A \cos \alpha x - 4B \sin \alpha x) + l^{-\alpha x}(- 4C \cos \alpha x - 4D \sin \alpha x)]$$

$$\frac{d^4y}{dx^4} = - 4\alpha^4 y$$

$$\alpha = \sqrt[4]{\frac{k}{4EI}}$$

The limit conditions are :

for $x = 0$:
(1) $\frac{dy}{dx} = 0$ by symmetry
(2) $T = -\frac{P}{2}$

for $x = l$:
(3) $\mathfrak{M} = 0$
(4) $T = 0$

After the necessary eliminations, somewhat lengthy but not difficult, we get :

$$A = \frac{P}{16EI\alpha^3} \frac{l^{-2\alpha l} + 2 \cos^2 \alpha l - \sin 2\alpha l + 1}{sh\ 2\alpha l + \sin 2\alpha l}$$

$$B = \frac{P}{16EI\alpha^3} \frac{-l^{-2\alpha l} + \cos 2\alpha l + \sin 2\alpha l}{sh\ 2\alpha l + \sin 2\alpha l}$$

$$C = \frac{P}{16EI\alpha^3} \frac{l^{2\alpha l} + 2 \cos 2\alpha l + \sin 2\alpha l + 1}{sh\ 2\alpha l + \sin 2\alpha l}$$

$$D = \frac{P}{16EI\alpha^3} \frac{l^{2\alpha l} - \cos 2\alpha l + \sin 2\alpha l}{sh\ 2\alpha l + \sin 2\alpha l}$$

For $x = 0$, that is to say, in the centre of the beam, we have :

$$y = \frac{P}{4EI\alpha^3} \frac{ch^2 \alpha l + \cos^2 \alpha l}{sh\ 2\alpha l + \sin 2\alpha l}$$

and we find at once that y is always $\geqslant 0$

$$\mathfrak{M}_0 = -\frac{P}{4\alpha} \frac{ch\ 2\alpha l - \cos 2\alpha l}{sh\ 2\alpha l + \sin 2\alpha l}$$ always $\leqslant 0$.

If α is small, that is to say, if k is small or if E and I are large, the first terms only may be retained in making the developments, whence we get a well known formula :

$$\mathfrak{M} = -\frac{P}{4\alpha}\left[\frac{8\alpha^2 l^2}{2}\right] - \frac{Pl}{4}$$

that is to say, an even distribution of pressure.

The deflection of the beam is :

$$y_0 - y_e = \frac{P}{8EI\alpha^3}\left[\frac{ch\ 2\alpha l + \cos 2\alpha l + 2 - 4\ ch\ \alpha l \cos \alpha l}{sh\ 2\alpha l + \sin 2\alpha l}\right].$$

If α is small, and confining ourselves to the first terms of the development, we get

$$y_0 - y_l = \frac{P}{8EI\alpha_3}\left[\frac{2\alpha^4 l^4}{4\alpha l}\right] = \frac{Pl^3}{16EI}$$ which is a known result.

Critical length. — The hypotheses made would assume that the beam is drawn downwards in the points where it is raised above its equilibrium position. Actually, this is not so at all, and the equations are no longer valid unless the beam becomes « loose ». This occurs at the end of the beam when $y = 0$ for $x = l$, that is to say for :

$$\cos \alpha l = 0 \quad \text{or} \quad \alpha l = \frac{\varpi}{2}.$$

The equations are therefore only valid for beams such that

$$l \leqslant \frac{\varpi}{2\alpha}.$$

For a timber sleeper 0.20 m. (7 7/8 inches) wide, 0.14 m. (5 1/2 inches) thick, placed on resistant ground $k = 10$, this critical length is

$l = 0.70$ (2 ft. 3 1/2 in.) approximately.

The moment at the centre of the beam is

$$\mathfrak{M}_o = -\frac{P}{4\alpha}\left[\frac{ch\, 2\alpha l - \cos 2\alpha l}{sh\, 2\alpha l - \sin 2\alpha l}\right].$$

If $l = \frac{\varpi}{2\alpha}$ critical length, we have, since the quantity inside the brackets only differs slightly from l.

$$\mathfrak{M}_o = -\frac{Pl}{2\varpi} = -\frac{Pl}{6.28} = \text{nearly } \frac{2}{3}\left(-\frac{Pl}{4}\right)$$

when the moment corresponding to the even distribution of the reactions is $-\frac{Pl}{4}$.

For the same value of l the maximum reaction at the centre of the beam is :

$$p_o = k\frac{P}{8EI\alpha^3}\left[\frac{ch\, 2\alpha l + \cos 2\alpha l + 2}{sh\, 2\alpha l + \sin 2\alpha l}\right]$$

$$p = \text{practically } \frac{P\varpi}{4l} = 1.6\frac{P}{2l}$$

the pressure exerted on the ground by the beam in its centre is equal to 1.6 times the mean pressure.

* * *

In the case in which the beam is loaded at its two ends by a weight P, we have as limiting conditions :

$$x = o \begin{cases} \dfrac{dy}{dx} = o \\ T = o \end{cases}$$

$$x = l \begin{cases} \mathfrak{M} = o \\ T = P \end{cases}$$

Calculations similar to those made in the first case lead to the following coefficients :

$$A = \frac{P}{2EI\alpha^3}\,\frac{ch\,\alpha l \cos \alpha l}{sh\, 2\alpha l + \sin 2\alpha l}$$

$$B = \frac{P}{2EI\alpha^3}\,\frac{sh\,\alpha l - \sin \alpha l}{sh\, 2\alpha l + \sin 2\alpha l}$$

$$C = \frac{P}{2EI\alpha^3}\,\frac{ch\,\alpha l \cos \alpha l}{sh\, 2\alpha l + \sin 2\alpha l}$$

$$D = -\frac{P}{2EI\alpha^3}\,\frac{sh\,\alpha l - \sin \alpha l}{sh\, 2\alpha l + \sin 2\alpha l}.$$

The beam comes away from the ground in its centre ($x = 0$) for a critical length $l = \frac{\varpi}{2\alpha}$. For this length, the reaction at the centre is zero and the bending moment at the centre is almost half of what it is in the case of the even distribution of pressures.

[385. (06.11]

Final summaries adopted at the eleventh Session, Madrid (May 1930).

SECTION I. — Way and works.

I. — The use of concrete and reinforced concrete on railways.

A) *Investigation into the respective merits of the different designs of concrete sleeper.*

B) *Concrete and reinforced concrete buildings.*

SUMMARY.

Part A. — Considerable progress has been made in concrete sleeper design. The detail of rail support and fastenings and the suppression of centre ballast have been given particular study. The recent installations provide resiliency at the rail support, and at the same time seem to secure electrical insulation between the rails. The suppression of centre ballasting and elimination of centre solid portion of sleeper have reduced the weight as well as the cost and also produced a sleeper better able to withstand shock and vibration.

The present status of this very important question appears very encouraging but the problem is by no means solved. Experiments and study should be diligently continued, taking into account the prime cost, so that we may hope to be nearer the final solution at our next session.

It is advisable to undertake systematic tests in the laboratory to investigate the resistance of concrete to dynamic repeated stresses by varying the nature and size of the aggregate and its cleanliness.

Part B. — The subject of improvements in methods of concrete making, better cements and aggregates and better reinforcement is of vital importance in the general need for stronger and more durable concrete. These should be given further study as well as the methods of more accurate proportioning by control of the water-cement ratio in order to advance the general knowledge of this very important building material.

It will be of interest to follow up more closely the question of super-cement and other cements of a special nature.

Investigation should also be made into the precautions necessary for avoiding attacks on the concrete and the oxidation of the steel in constructions in the neighbourhood of the sea or which are exposed to chemical action.

As regards rail-carrying bridges it would be advisable to place these under systematic observation with a view to obtaining sufficiently conclusive details on the manner in which such constructions behave in use and more especially under dynamic stress.

It is also recommended, in the case of constructions of a certain magnitude, that experiments in the construction-room shall be increased so as to verify the constancy of the quality of the concrete.

II. — Resistance of rails against breakage and to wear.

A) *First causes of rail breakage; measures taken to reduce the number of*

breakages, both as regards the way rails are used and the conditions of inspection.

B) *Quality of metal used for rails to give normal wear. Conditions governing manufacture and inspection.*

Rails : profile and quality, length, weight, and cross section of the rails.

C) *Rails joints. The most economical and efficient design.*

SUMMARY.

The various observations and recommendations relative to Question II (Resistance of rails to breakage and to wear) may be summarised as follows :

1. It is desirable to continue the publication of data relative to rail breakages under the conditions laid down at the London Congress, the tables, however, being slightly modified.

2. It is highly desirable to continue the observation and study of rail breakages, and it is recommended that this should be done in collaboration with metallurgical engineers.

3. It is desirable that the precautions indicated below should be observed in the manufacture of rails :

a) dose the steel in such a way as to avoid blow-holes;

b) forbid the use of steel scrap at the bottom of the ingot moulds;

c) avoid splashes when pouring;

d) not to roll ingots too hot;

e) not to force the speed when blooming, so as to avoid the formation of cracks;

f) discard from the ingots the part affected by piping and segregation;

g) terminate rolling at a temperature as near as possible to that of the critical point;

h) establish and maintain the profile of the grooves on the rolls with accuracy;

i) reduce to a minimum the cold straightening of rails, so as to diminish the stresses resulting therefrom.

4. It is recommended that the following should be developed :

a) macrographic tests so that the homogeneity of the cross section may be examined. In their present form, these tests can be used for elimination purposes *i. e.* for the elimination of rails which are not uniform throughout;

b) elasticity tests for determining the degree of fragility of the metal. These tests, in their present form, do not enable fragile rails to be rejected, but they are already sufficient to serve as a basis for the granting of quality premiums. It would be an advantage if research could be continued in order to perfect a fragility test applicable to the whole cross section of the rail;

c) laboratory research and tests relative to the endurance of rails, *i. e.* to their resistance to repeated stresses;

d) research and experiments relative to the stresses which develop in rails under passing wheels.

5. The following precautions are recommended when laying rails :

a) To utilise rails obtained from the head of ingots in those parts of the line which are least heavily stressed;

b) to load and unload rails by mechanical means;

c) to inspect the rails in situ, at least once a year, on lines where traffic is intense. It is desirable to perfect appliances for detecting internal defects in rails

whilst in service (Sperry detector, Suzuky defectoscope);

d) to use rails which have received suitable heat treatment on sections of line where the rails are subjected to exceptional stresses, to skidding and to repeated braking, as rails so treated resist the propagation of superficial fissures (cracks in the running surface) better than rails which have not been treated.

6. The length of rails (of medium weight) can, without inconvenience, be increased to 24 m. (78 ft. 9 in.), and research and tests should be continued with a view to increasing the length beyond 24 metres (if necessary by means of aluminothermic welding), particularly at special points of the line where the effects of expansion are less to be feared.

7. With a view to reducing normal wear in rails, it appears desirable to give the running surface, when new, the average cross section which it tends to assume in service.

8. With a view to reducing lateral wear on curves, appliances for lubricating the lateral faces of the head of the rail and of the wheel tyre which come into contact during running on curves, should be perfected and developed, or special or heat treated steel rails should be used.

9. With a view to reducing wear through hammerings at gaps in points and crossings, it is recommended that use should be made, in the details or such equipment, of manganese or nickel-chrome steel.

10. With a view to remedying wear due to rusting, it is recommended that a reinforced cross section be adopted. The tests with steel containing an admixture (0.3 %) of copper should be continued.

11. It is desirable that all railways should continue and develop the comparative tests of rail joints suggested by the London Congress, and that they should extend these tests to the following two new types of joint :

— head-free fish-plate;
— chevron fish-plate.

12. It is recommended that each administration should keep statistics relative to the breakage of the different types of fish-plates used in the comparative tests.

III. — Investigation into the static and dynamic stresses in railway bridges.

SUMMARY.

1. It is desirable that the railway companies should continue experiments and the study of secondary stresses, with a view to furnishing supplementary information on the occasion of another Railway Congress.

2. The advantages of eventually establishing and adopting a definite formula for the impact allowance in terms of the span in feet are that it would assist greatly in the standardisation of bridge work.

3. Care should be taken that the treads of the wheel tyres are regular — flats capable of serious damage should be avoided.

4. Particular care should be paid to the upkeep of the track on the bridge floor and at the approaches.

Care should be taken that the joints of the rails are kept in order — if possible they should be placed off the bridge, at all events as close as possible to the supports. The trials of welding the joints

on bridges will be followed with interest, this measure, if successful, being extremely favourable to the reduction of impact.

It is also advisable to strengthen the sections of the track at the approaches to bridges, so as to avoid rapid variations of the equilibrium of the locomotive on its springs.

5. The influence of the excess counterbalance weights of locomotives should be diminished by distributing the weights between groups of three adjacent coupled axles.

IV. — Recent improvements in permanent way tools, and in the scientific organisation of maintenance work.

SUMMARY.

1. The track work which is usually done with special equipment (apart from the use of small tools like jacks, poney-cars, etc.) are :

a) Unloading the ballast by means of special wagons;

b) Tamping the ballast by means of pneumatic or electric tampers;

c) Weeding the ballast by chemical means.

2. Track work for which mechanical tools deserve to be considered are :

a) Unloading rails and re-loading rails and permanent way material;

b) The mechanical compression of the bottom ballast;

c) Laying of complete sections of track;

d) Oiling the running side of rails on curves;

e) Driving coach screws and possibly tightening fishplate bolt nuts mechanically.

3. Apart from cranes which are usually driven by a steam engine or Diesel or internal combustion motor, both pneumatic and electric machines meet all needs.

4. The economic advantages are in several cases very appreciable and show savings of as much as 50 %. In order to get a satisfactory output from the machines, it is necessary to regulate strictly their use by drawing up a programme of work.

5. Apart from economy, the use of machines can lead to other advantages such as better work, less fatigue for the workmen, work carried out in shorter time, and the possibility of making up for a shortage of labour.

6. In the organisation for maintaining the track, several innovations have been introduced with a view to economy. The chief innovations are : the extension of maintenance by general revision; reducing the strength of the gangs in winter; increasing the area covered by the gangs; the employment of auto-cars for transporting men, stores, and mechanical tool equipment.

7. The length of the road to be maintained by a brigade and the strength of the brigades differ within wide limits.

A rational basis for determining the number of men required for maintenance is the length of equivalent track, which is to be calculated by means of formulæ.

It is necessary to introduce into these formulæ all the factors bearing on the maintenance, giving them their appropriate coefficients.

8. Maintenance by general revision is to be recommended, not only as an economic measure, but also in order to have an effective control of the personnel entrusted with the maintenance of the road.

9. There are only a very few Administrations who have certain work carried out by their personnel by piece work, or who grant premiums for the execution of certain work within a fixed period. Nevertheless, this practice deserves attention, as much from the economic point of view as in the interest of the workmen, the fear that the quality of the work will suffer, not being justified.

10. The 8-hour day (48 hours per week) or a period which does not materially depart therefrom is fairly general. Often in summer the day is longer, but in winter shorter, than the normal day.

11. Generally the working time begins to count from the moment when the workman arrives at the designated spot, either the gang depot or a station, or the place where the work has to be done.

12. The use of auto-cars to take men to their work is not very general, and is only indicated where work is started habitually at a place other than at which the men are concentrated.

13. In order to increase the life of the materials used, the following measures should be adopted : heavy rails, special steels for rails and points, hard wood sleepers, heavy base plates, broken hard stone for ballast, increasing the number of sleepers, lubricating the fish-plates and the running side of the rails on curves, repairing worn parts and subsequently using them again.

14. The use of graphs shewing the progress of all works, with the indication of the economic results obtained is not very general. These graphs should be used increasingly, but they should be of the simplest possible form.

SECTION II. — Locomotives and rolling stock.

V. — Locomotives of new types; in particular, turbine locomotives and internal combustion motor locomotives.

Construction, efficiency, use and repair.

SUMMARY.

The Congress recommends to the Railway Companies and Administrations present :

1. To encourage efforts to create new types of locomotives and to improve the current Stephenson type of locomotive by facilitating in particular the initiative of locomotive builders.

2. To develop further in particular the use of extra-high steam pressures and the internal combustion locomotive.

3. To carry out methodically trials of locomotives of new types and different designs built by various makers and to publish the results of such trials systematically and as made.

4. To co-operate with a view to the erection of locomotive experimental stations: the international collaboration of such stations would facilitate progress in scientific locomotive design.

VI. — Improvements in the steam locomotive.

Increased pressures and higher super-

heats. Improvements in the design of superheaters and parts connected with superheating. Feed water heating and air preheating. Improvement of valve gears.

SUMMARY.

The Section decided that the above summary relating to question V would also apply to question VI, after being completed as follows with regard to steam reciprocating locomotive :

Among the recent improvements which have taken place in steam locomotives of normal construction, special attention should be given to :

a) Increase in the temperature of superheat, and

b) The pre-heating of the feed water.

Taking into account the numerous trials which have been carried out by many of the Railway Companies, and the experiences gained over many years, this Congress is of the opinion that :

a) The temperature of superheat can, in practice, be taken to 400° C. (752° F.), special attention being given to lubrication and the method of steam distribution;

b) That there are in service methods for pre-heating of water which are giving satisfaction.

The Congress recommends the adoption of these two improvements on account of the important economies which can be realised from them.

VII. — **Electric locomotives for main line traction.**

a) *passenger locomotives;* b) *goods locomotives;* c) *locomotives for mountainous country. Multiple unit traction.*

SUMMARY.

1. The Congress finds in the first place that the electric locomotive does not present the similarity of arrangement that the steam locomotive already had a few years after its invention and in which direction it has since continued.

2. The different methods adopted for the transmission of power from the motors to the wheels and for the arrangement of trucks, have in almost all cases given satisfaction.

The Congress particularly recommends to the Railway Companies the carrying out of methodical trials, with a view to determining whether, at high speeds, electric locomotives with motors suspended by the nose have a more injurious effect on the track than other types.

As regards locomotives without coupling rods, and with motors completely suspended from the frame, the Congress recognises that, all other things being equal, one can adopt a heavier weight per axle than with locomotives in which certain masses are reciprocating, not being completely balanced, — as is the case in fact with the majority of steam piston locomotives.

3. From the electrical point of view, the Congress appreciates that as a result of the improvements in recent years, and having in view the arrangements which have been made to protect the staff against accidents, locomotives of different types give general satisfaction from this point of view of their functioning, and give perfect protection to the staff.

Traction motors in particular at present give complete satisfaction as regards heating, power and commutation.

However, the Congress calls attention of designers to certain details of construction such as the insulation of various parts of the motors, etc., with a view

to reducing damage which occurs from time to time.

Consequently, the Congress trust that attention will still be given to these points with the object of developing new technical methods of testing, which at the present time are being considered by several international Associations.

4. The Congress also notes that from the point of running and regularity of service, recently constructed electric locomotives give satisfactory results.

It requests the various Companies and Administrations to regularly and freely publish the results of operation on their electrified lines with a view to helping other Administrations in the study of new applications of electric traction.

VIII. — All steel coaches. Comparison with vehicles built of wood.

SUMMARY.

1. In those countries in which the operating conditions permit the construction of all-steel carriages, experience has shown that conditions of safety sufficiently justify the adoption of this construction for new work.

2. To prevent excessive weight, it is desirable that the body should take part of the stresses.

Coaches built on this principle are very little heavier than coaches with wooden bodies offering the same standard of comfort.

3. In this form of construction it is possible to combine rolled sections, bent and pressed flat plates, cast steel and malleable iron castings.

In every way metal construction lends itself to the mass production of standardised parts. In order to lessen the weight of metal carriages, several administrations have carried out trials with high-resistance steels and light alloys. The Congress recommends that the study of the use of these metals should be continued.

4. Assembly can be done by means of rivetting, oxyacetylene welding, arc or spot welding or by a combination of these methods.

5. The interiors can be fitted out in the same way as wooden vehicles. They can however be given a distinctive appearance if the metal plates are left visible and the interior decorations treated accordingly. In most cases metal coaches can be fitted up so as to assure to the public a degree of comfort equal at least to that of the vehicles with wooden bodies.

6. The methods of construction are still too varied and the vehicles on numerous railways have been put into service too recently to allow precise conclusions to be formed regarding the first cost of construction and the repair charges. Results so far obtained however have been encouraging.

7. Numerous experiments have still to be made both as to the choice of the methods of construction and the materials to be used in fitting out the interior, such as heat insulation of the body sides, the floor covering, interior linings, breakage of glass, painting, and protection of plates against rust.

SECTION III. — Working.

IX. — Relations between railways and sea ports.

Lay-out of maritime stations; arrangement of outer and inner basins so that the most efficient lay-out of sidings may be provided for working them; operating and rate fixing methods; loading and discharging appliances.

SUMMARY.

1. In principle, one harbour concentration yard is preferable. Nevertheless, several may be justified, as follows :

a) Under certain geographical conditions;

b) If the volume of traffic exceeds the capacity of a single concentration yard;

c) When certain specific traffics are ensured by special trains entirely independent of the general services.

2. The stations should have separate groups of sidings and running lines for inwards and outwards traffics.

3. The yard should be sufficiently large to take up the repercussions due to temporary cessation of traffic movements in either direction.

4. The concentration yard may be used for shipping, local, and through railway traffics, so long as the limit of capacity of a single yard is not exceeded and the organisation of the maritime service does not suffer.

5. The shunting may, with advantage, be concentrated in the harbour station, and the shunting at the quays limited to sorting to hatches and destination order when loading direct into ships, or to shed or warehouse bench order.

6. Ample holding tracks should be provided at the quays to ensure continuity of service at the ships or sheds.

7. Wagons discharged at the quays should not be passed empty to the concentration yard if they can be reloaded at quays to which they have ready access.

8. Consignments for export should not be split up en route unless the traffic is passing in such volume that continuity of loading can be maintained.

9. The lay-out of harbours, and particularly the orientation of jetties and moles, should permit of the adoption of easy railway curves : for normal gauge, a curve of 120 metres (6 chains) radius is considered to be the minimum. It is desirable to increase this to 150 metres (7 1/2 chains) for tracks used by the larger locomotives of normal type.

The figures relative to wide and narrow gauges should be arranged according to the respective necessities.

10. It is important not only that the quays be constructed of sufficient width in relation to the size of the dock, but also that sufficient space should be reserved on the quays for the railway to lay down methodically its lines in order to allow such speed of movement to trucks as will meet the requirements of commerce.

11. There should be at least three tracks alongside the quays with crossings at intervals in order to give the best working facilities.

12. Switches should be used generally and are preferable to turntables or traversers for shunting purposes.

13. At quays where road vehicles are largely used, quay tracks with grooved rails sunk to the ground level are convenient, and this arrangement permits tow-motors to be used in place of ordinary locomotives for shunting duties.

14. The capacity of quay cranes should not exceed the weight of the bulk of the articles to be lifted. Dual capacity cranes are economical and provide for occasional lifts that are heavier than normal.

Cranes should be arranged to give free movement of wagons along the quays and to have sufficient reach to plumb the wagons on the quay lines and the further side of the ships' hatches.

Cranes of the luffing type have many advantages.

High capacity floating cranes are considered to be the most satisfactory means of handling heavy lifts.

For loading and unloading wagons and sorting and storing traffic in sheds and warehouses, travelling bridge cranes fitted with revolving jibs which can be projected through the shed sides over outside wagon tracks are efficient.

The number of quay cranes per berth is considered to be as important a consideration as the determination of their capacity. The number should not be less than the normal number of hatches in vessels regularly using the port.

15. In order to hold to a port any specific heavy traffic, it is indispensable that special accommodation be reserved for it, adequately provided with appropriate handling contrivances.

16. In order to reduce the time wagons are detained, the prescriptions regulating the penalties for delay ought to be as stringent as permitted by operating and labour conditions, so as to constitute a safeguard against blocking up the harbour and against immobilisation of the railway rolling stock.

17. The organisation of the staff of the harbour, the railway and the customs is of the highest importance and ought to be such as to enable all services to work smoothly and rapidly.

Finally, too much stress cannot be laid on the necessity for a close collaboration between the railway companies and the port administration when it is proposed to alter or extend existing harbours or to establish new ports.

X. — Methods to be used in marshalling yards to control the speed of vehicles being shunted, and to ensure they travel on to the lines in the various groups of sidings.

SUMMARY.

1. The methods employed in marshalling yards to control the speed of vehicles being shunted consist of :

A. A rational disposition of the lines and of their profile in order to ensure the most rapid shunting possible.

B. To obtain the necessary slowing down :

a) Braking appliances fixed to the vehicle (hand-brakes) ;

b) Portable shoes or slippers placed on the running rail or track by hand;

c) Shoes, slippers or skates placed on the running rail or track by mechanical (including electrical) means such placing being controlled from a distance;

d) Rail brakes or retarders parallel to the running rail or track, exercising either a lateral braking effect on the sides of the wheels of vehicles, or a braking effort induced by eddy currents, this braking being controlled from a distance.

2. Hand brakes *a*) and portable shoes *b*) necessitate the personal attendance or accompaniment of personnel for the purpose of applying braking when necessary and to the desired extent.

3. Distance operated shoes or skates *c*) and rail brakes *d*) permit of completely or partially centralised control of braking requirements, and enable some reduction in braking personnel to be effected.

4. In hand and portable shoe braking, as practised in England, the responsibility may be divided between a number of individuals.

5. In distance shoe or rail braking the responsibility is concentrated in one or a very few individuals who require to be located in an elevated position commanding a bird's-eye view of the sphere of operations.

6. At all large yards, where hump or gradient shunting is in operation or when new yards are contemplated, consideration should be given to the question of installing distance-controlled shoe or rail braking methods.

7. The difference in conditions, capacity and weight of vehicles in general, in the different countries, combined with the fact that distance-controlled shoe or rail brakes are in the process of development and improvement and the lack of experience of them in certain countries, prevent any general conclusion being reached in favour of a particular type.

8. The initial cost of introduction or conversion to complete distance-controlled shoe or rail braking is high in comparison with methods employed hitherto, but savings varying in extent in different countries, by the reduction of personnel, can be effected, of a permanent and continued character.

9. The economies can be supplemented by grouping together the control of point or switch operation in the same location as the shoe or rail brake control. It may be desirable that the points should be « quick-acting » and it is advantageous, at high capacity hump yards, for the points to be capable of being pre-set electrically and automatically changed by the vehicles themselves.

10. The primary considerations in regard to the gradient and height of the hump for distant-controlled shoe or rail-braking are that it shall be such that the worst running vehicle under the most adverse conditions, curvature of track, weather, etc., shall reach the full distance required. Also that the preliminary character of the gradient shall be such as to give a sufficient impetus to vehicles or cuts at the start, so that they are sufficiently separated prior to reaching the points or switches and shall not stop in the point or switching area.

11. The necessary brake pressure to absorb, if required, the surplus speed can be concentrated or spread out through several appliances according to the power of the type employed.

The space available could be taken as the predominating factor as to the type

of apparatus to adopt. It may be necessary, even with a very powerful type of apparatus, to possess several series of brakes in order to regulate the speed during the run from the hump and to maintain the space between wagons of a different co-efficient of running.

12. In principle, in mechanical brake installations, the first set is usually placed at the foot of, or immediately below the first or steepest part of the gradient with as many more sets as may be necessary, on the leads into the groups of sorting sidings, with a further set at the commencement of each of the individual sidings clear of the point or switching area.

13. In purely rail braking installations the brake rails, one set or more as necessary, are usually located in the leads to the various groups of sidings only.

14. The greater the extent to which braking power, with the necessary elasticity of application, can be concentrated in the fewest appliances, the less staff of operators is required, so that the work can be speeded up, as an operator, instead of having to watch a vehicle or cut through a succession of brakes, can the sooner turn his attention to the next oncoming vehicle or cut.

15. Certain forms of rail brake make it possible to obtain a braking force proportional to the weight of the vehicle or cut, which is an advantage, provided the construction is such that light vehicles are not lifted out when pressure is applied.

16. The initial cost of such rail braking appliances is at present comparatively high and they necessitate certain standard features of design of layout of track, *i. e.* the balloon-shaped formation, with points or switches at more or less equal radii from the hump.

17. The initial cost of shoe braking apparatus is stated to be appreciably less and in suitable instances may be applied to existing lay-outs.

18. Certain types of rail brake are of such length that brake pressure can be increased or decreased at will as vehicles or cuts of vehicles are passing through them.

19. With the shoe brake there is not the same facility, as once the wheel has mounted the shoe the pressure is constant until the shoe leaves the track at what is a fixed position or cut-out.

20. One form of shoe brake has its normal rest position at the lower end of the brake area and is propelled towards an oncoming vehicle to the pre-judged distance necessary, by the operator at will.

21. Another form of shoe brake has its normal position at the higher or commencing end of the braking area and may be placed on the rail at will by the operator as necessary and provides for the return of the shoe to the starting point automatically.

22. Rail brakes may be operated or controlled electrically, hydraulically, or pneumatically, or in part combination.

23. A purely automatic shoe braking appliance governed by the speed and weight of vehicles approaching and by the extent of occupation of the siding to be entered is in the experimental stage but this as yet appears to necessitate limiting to two at a time the number of vehicles being shunted.

24. Another appliance of interest which is at present being tried out is an accelerator which gives an additional impulse to badly running wagons or during unfavourable atmospheric conditions.

25. A sufficient lighting arrangement of a modern type is desirable for all large marshalling yards, and particularly where rail braking or shoe braking methods are in force.

26. Luminous signalling devices providing suitable code is advantageous for controlling speed of hump operations, being duplicated as necessary and supplemented by oral code signals such as electric or klaxon horns if required. It is found desirable to develop increasingly the systems which allow of the chief foreman directing operations to himself order the movements of wagons from the train about to be shunted.

27. Mechanical means for the transmission of cut lists or other documents afford a desirable means of expediting the conveyance of train papers, cut lists, etc., between the essential posts in the yard.

28. Electric teletype machines afford a ready and expeditious means of transmitting at one operation the switching or cut lists and of giving instructions to the rail brake and point or switch operators' cabin and other parts of the yard as necessary.

29. Loud speaker telephones for verbal messages are of considerable benefit for rapid communication between certain key positions in a hump yard.

30. In general the advantages claimed for distance-controlled braking methods embrace some, if not all, of the following advantages, according to local circumstances, and the particular type of apparatus used :

a) Reduction in number and cost of brakesmen;

b) Damage to goods and rolling stock diminished, with consequent reduction in claims and maintenance costs;

c) Increased safety of employees;

d) Slow working due to adverse weather conditions is counteracted;

e) Operating capacity of yards is enlarged;

f) Closing of small yards by concentrating the work at one large yard;

g) Certain yards closed during part of the 24 hours;

h) Avoidance of employment of extra staff in bad weather, or when extra shunting has to be done.

i) Reduction in locomotive-hours.

31. In certain instances where space permits, economical use has been made of small tractors capable of running between the different sidings and crossing the rails when necessary, for the purpose of propelling or hauling one or more vehicles at a time and assembling the vehicles which have been shunted.

XI. — Signalling of lines for fast traffic and in main stations. Daylight signals. Automatic block system.

SUMMARY.

I. — (Which completes resolution 1 of the London Session.)

As the *basis* for signalling express train routes a stop signal with two positions and an advance signal also with two positions are necessary.

The determination of the minimum distance between advance and home signals should be based upon the most un-

favourable conditions of braking and visibility.

An extension of this signalling by additional signal positions may be necessary for the following purposes :

A. — *Home signals.*

1. To specify a speed limit through points adjacent to home signals (when branching off), or

2. To indicate the route (at turn-outs).

3. To permit the permissive passing of home signals after a preliminary stop.

4. To permit heavy goods trains to run slowly past the stop signal on gradients.

5. To specify speed limits through the section or on approaching the next home signal.

B. — *Advance signal.*

1. To indicate a limitation of speed (A1 or A5).

2. To indicate the route at the junction (A2).

It is indispensable to reduce to a minimum the number of indications given by the signals, particularly in places where a number of signals are grouped and the suppression of the less imperative signals is to be recommended.

In this connection mechanical signals giving three or four positions, and luminous (daylight) signals, offer great advantages, particularly when the distance between stop signals is small. The safe working of the service however places a limit on the elimination of signals.

II. — (Completes resolution II of the London Session.)

In certain cases, the use of a disc signal, placed on a level with the eye of the driver, can also be considered.

III. — (Completes resolution III of the London Session.)

Any further signal positions that are necessary can be obtained by grouping these lights in pairs or banks, which may be vertical, horizontal or diagonal, or by the addition of a marker light, or by a flashlight arrangement. Care must be taken that the extinction of one light does not result in an indication less favourable to security.

IV. — (Concerns resolution VI of the London Session.)

The use of luminous signals, and particularly of coloured light signals, is becoming more and more general even on non-electric systems.

Daylight signals have the avantage over position signals (semaphore—disc), that their visibility is not affected by an unfavourable background, by mists or by twilight; they avoid moving parts which may be affected by frost. Daylight (luminous) signals are particularly suitable for giving more than three signal indications on one signal, by the supplementary use of various groupings of pairs of coloured lights. A comprehensive signal of this kind which shews to the observer at any time only one definite signal aspect is preferable to the combination of several two or three-aspect conformation signals.

Special care must be taken to see that a good horizontal dispersion of the luminous rays at curves is given, to the good visibility of the signal to a train arrived at its foot as also to the guarantees of security as regards the source of supply of electric current.

V. — (Completes resolution VII of the London Session.)

Automatic block-working with suitable lay-out and methods of installation gives a better safeguard against incorrect signalling than manual block-working. The automatic block-system allows of an economy which is increased commensurately as the distance is increased between the cabins which it is necessary to have manned. It would further appear that in the present state of technical progress, the automatic block system should be limited to lines constructed with wooden sleepers and, when these carry dense traffic, it should be installed only where there is no objection to the permissive passage of a train into an occupied block section. The tendency is towards simplification in working methods which, without diminishing safety, shall reduce to a minimum delays due to failures or irregularity.

VI. — The use of power operation has rendered possible the control of extensive station installations from a *single* control frame. Such centralisation is particularly expedient when the outlying points are not used for shunting.

The control of the whole of the safety appliances of a long stretch of line from a single dispatcher point has proved to be practicable, low-voltage batteries being installed locally for operating the points by means of slow-running motors. It is desirable to continue investigations on this subject.

VII. — The methods adopted for ensuring the *safety of shunting movements at large stations* are on some railways similar to those used to safeguard the running of trains; on another group of railways, however, these safeguards are dispensed with and they are satisfied to protect the traffic against shunting by safety switches, train locks or mechanical blocks or derailers.

It is desirable that further consideration should be given to this question, also to the advisability of making use of main signals for ensuring the safety of shunting traffic.

XII. — **Economical traction methods for use in particular cases, as for example:**

A) *Organisation of train services on the minor lines of the large systems carrying little traffic, and of little used trains on the more important lines of these systems.*

B) *Use of special tractors for shunting in smaller yards and for certain work in large yards.*

PART A.

1. The prime movers mainly used in train working on those lines of the great railways with little traffic and lightly loaded trains on the more important lines are steam locomotives of varying weight, of the ordinary types.

2. Many of the railways also use rail motor coaches with or without trailers, with a steam or internal combustion engine (explosion or Diesel), or with accumulators, the power usually reaching 100 to 150 H. P., or more, and in addition Diesel locomotives. There is a marked tendency to extend the use of such vehicles. Their substitution for heavy trains allows of higher speed and supplementary stops between stations without prolonging the total duration of journey. Their introduction, however, is of too recent date for definite conclusions to be formed concerning the economies resulting from their use.

3. It is quite usual for vehicles fitted with an internal combustion motor to be driven by a single man; steam locomotives are usually worked by two men.

4. It is not possible to form any conclusions as to which system is to be preferred, since only long experience can furnish the data necessary for arriving at a definite conclusion.

PART B.

1. Electric capstans, alone or in conjunction with turntables; electric traversers and traversers hauled by a capstan or « locotractor ». The traversers are especially valuable for shunting on lines to which access through points is not possible.

2. « Locotractors » with or without a capstan and worked by a single man. These « locotractors » are usually fitted with a petrol engine, sometimes with a Diesel or steam motor or with electric motors with accumulators.

Certain of these systems have not yet been used sufficiently, in practice, to allow of a choice being made between them.

They can be run on any track accessible to wagons.

They can moreover be adapted for shunting at a particular station, or adapted for working several stations by travelling from one station to another on the main line.

Petrol, Diesel and accumulator tractors have the advantage over steam « locotractors » of being always ready for work, and can be driven by the ordinary station staff.

3. Road tractors, — independent of the track and therefore very flexible in use. These are particularly suitable for operations otherwise carried out with the help of horses.

4. By road tractors or tractors for narrow gauge lines specially laid down in shunting yards for assembling marshalled wagons, without stopping marshalling operations. These above all increase the capacity of marshalling yards, and provide means of reducing damage to trucks and of reducing working costs.

II. — Horses have practically ceased to be used for traction purposes.

SECTION IV. — General.

XIII. — Competition of road transport.

Effect of road competition on goods and passenger traffic and the best methods of meeting such competition, both as regards the main lines and the branches.

SUMMARY.

1. Because of the growing importance of road motor transport, and its competition with railway transport, the common interest of both methods of transport, as also the public interest, requires an exact appreciation of their respective values as regards communications as a whole : also the coordination of their services.

To attain this end it is necessary to modify the present position of road motor transport, which in most countries gives it an advantage over the railway,

also to make road transport bear its full share of road expenses : in short that the public charges shall be equally divided between these two methods of transport.

2. The system of free competition allowed in some countries, or the purely formal authorisation of regular motor services without regard to existing communications and without sufficient guarantee of the civil responsibility of the concessions-holders, is not at all in the interest of the public.

The concession of regular motor services competing against the railway or other communications already in existence, which do not give the public any new advantages, should be prohibited. Before granting authority or a concession for any regular motor service, the authorities concerned should be obliged to take into account the railways of the district and consult the owners thereof.

3. The indisputable advantages of motor transport, such as direct door to door services, operation by small units running frequently and rapidly, immediate organisation of a service with but little capital expenditure, are a valuable adjunct to the railway in many cases — services between stations, tourist services, etc., — and everything points to the advantage of collaboration between it and the railway, which is the best method of transport for large numbers of passengers and quantities of heavy goods.

To assure as far as possible a close collaboration between motor and the railways for transport as a whole, the railways should have the preference for obtaining the concession of regular motor services where they are prepared to take advantage of it.

4. The competition of road transport is greatest over short distances [up to 50 or 100 km. (31 to 62 miles)] and causes the diminution of railway traffic, varying according to the number of the road vehicles and other circumstances; cases have been stated in which this loss has reached 24 % of the passenger receipts of trunk lines, and up to 60 % of those of local lines, and 10 % of goods on trunk lines.

These figures include the losses due to the competition of irregular enterprises, as well as cars and lorries owned by private individuals, which, in certain countries where motor traffic is highly developed, are much greater (four times as much in Germany) than the losses due to the competition of regular motor services.

5. The costs of passenger transport on regular lines of motor omnibuses are usually about the same as second class on the railways, but in certain countries they are 60 % higher, in certain others they are lower than this.

Goods rates for road transport are based on railway operations and are, for short distances, generally lower than the latter, but in certain countries several times greater.

The diversity of these charges proves that the road transport competition, particularly for passenger traffic, must in some cases be attributed to causes other than economy.

6. To lessen road motor competition, the following improvements of rail transport have been successfully applied :

a) *Passenger traffic.*

Organisation of local services of light and frequent trains in the form of rail motor cars for lines of light traffic, with provision for numerous stops between

stations, organisation of through trains over branch lines; organisation of trains at reduced costs at holiday times, improvement of train connections at junction stations, sleeping cars and upholstered seats in third class carriages, delivery of luggage, etc.;

b) *Goods traffic.*

Speeding up of transport by means of direct services and complete loads, in certain cases attached to passenger trains; the reduction of time on the journey and stops at stations; reforms in the consigning of goods, especially of parcels, with the object of facilitating their collection and delivery, and speeding up their conveyance; a more prompt forwarding of goods from transhipment stations : organisation of private depots for traders, etc.

7. Road arrangements for ensuring a complete door to door service have been completed on certain railways in the form of motor lorry services organised by the railway company itself, or by means of agreements with private undertakings.

8. The use of containers, which can be loaded either on wagons or motor lorries, is increasing rapidly on some railways and facilitates direct transport for « smalls » traffic.

9. A great many railway companies are organising regular motor services as subsidiary undertakings, to act as feeder services, or to run parallel lines to relieve local congestion. Some of these railway companies (Pennsylvania Railroad — the Great French Companies — Dutch Railway Companies — Swiss Federal Railways — Italian State Railways) have entrusted the running of their regular motor services as well as the cartage services, and the investigation of questions connected therewith, to companies that they have organised as independent undertakings on capital provided by the railway. According to the information received these two types of subsidiary undertakings give promise of excellent results due to the collaboration of road and rail, and it is to be hoped that regular statistics will be established on this and other matters.

10. Mixed services of transport by rail and regular lines of motor buses belonging to the railways, or other undertakings, with optional itinerary, have been organised by several railways in the U. S. A. as well as in Europe and appear to be developing.

11. Numerous reductions of passenger fares and goods rates have been made by many of the railways, particularly for journeys up to 100 km. (62 miles) for certain competitive traffics.

The unfair position of railways in relation to road transport because of their obligation to adhere strictly to fixed tariffs has compelled several governments, Denmark, Holland, Italy, Rumania, Switzerland, Czecho-Slovakia, to make special agreements between the railways and traders for transport at reduced rates, for a fixed period, of agreed quantities of goods. This measure has proved successful so long as the rates agreed on correspond with the reasonable cost of transport by lorry, and give the railways something in addition to the actual cost. It appears desirable to bring this system into general application.

12. The Railway Congress emphasizes the fact that the rail remains the most economical form of transport having regard to actual cost, between the points it serves, and beyond that it is necessary in the public interest that railways should

retain their traffic. Railways have to contend with the following difficulties :

I. — They are subjected to legal obligations or regulations of a very onerous character;

II. — They are burdened in many countries with financial and fiscal charges higher than those of any other mode of transport.

In order to avoid serious consequences, economic and financial, it is necessary to remove these two causes of inequality,

13. Road transport has taken from the railways the monopoly of cheap and rapid communication which they formerly possessed in the localities they served. The present legal regulation of railways in the different countries takes no account of the profound change in their situation in this respect.

It appears to be necessary to lessen the burden of this legislation, which is one of the principal causes of successful road motor competition, which is often prejudicial to the public interest, also to make rating systems more flexible in order to place railways on the same footing as road motor organisations.

14. The information furnished by the administrations, and other documents, prove that the competition of road transport, which is very serious on certain systems because of local circumstances, has been lessened on other systems by the improvement and speeding up of rail transport, by the organisation of regular lines of automobiles forming auxiliary services and by mixed services of direct transport as well as by other measures, technical and commercial, of the railway administrations, supported by government regulations.

Projects of legal reform with the object of regulating the obligations and charges of road motor services as well as the easing of certain obligations of the railways have been reported by several administrations.

These examples make possible the hope that motor transport, duly co-ordinated, will become a powerful ally of railways and assist in completing and developing communications for the benefit of the community.

With this end in view, the further study of the question by the administrations and by the Congress is strongly recommended.

XIV. — Use in railway work of machines for simplifying statistical and accountancy work.

SUMMARY.

1. The efforts to make the operations necessary for the carrying on of correspondence, accounting and statistical work more economical, are a part of the great question of measures to be taken for rationalization. The objective may now and then be reached by pure and simple rationalization, but more generally by rationalization coupled with mechanization.

2. In order that when choosing the means, the appropriate ones may be selected, it appears worthy of recommendation that every Administration should set up a special department whose duty should be to investigate uniformly the basic questions concerning rationalization and mechanization and which, with its accumulated knowledge, should stand behind the detached departments in an advisory capacity.

3. The common axiom governing mechanization should be : The introduction

of office and similar technical apparatus is justified when, after taking into consideration purchase and high amortization costs due to rapid depreciation, savings are made or indirect advantages, such as the quickening or improving of work, are gained, such as will offset the costs.

4. Accurate judgment on the economic results of mechanization presupposes the existence of comparative accounting. The prompt production of the costs incurred by the introduction of machines and the working out of the costs of mechanical methods should therefore have careful attention.

5. The degree to which machines are occupied has considerable influence on the cost of mechanical operation. The policy of keeping the machines fully employed is therefore of the utmost importance in the organization of the work; in many cases, the centralization of work will be a preliminary step.

6. The office machines, mechanical installations and similar apparatus at present to be found in the use of the railway administrations, are of extraordinary diversity; on account of the continued progress in this sphere, each Administration must in future choose in the light of the common point of view previously developed, the machines which are best suited to its particular needs and operations; an interchange of ideas at a later date is to be recommended, on the experience accumulated, especially that concerning machines built solely for railway purposes such as ticket printers and the like.

7. An advance of the very greatest importance in statistical and accounting operations is to be seen in the introduction for statistical purposes of the so-called perforated card machines. Their advantage lies in the possibility of carrying out certain investigations more rapidly and more accurately and in the possibility of deepening the researches and opening up fields of enquiry which could not be reached by purely manual methods. Enquiry is therefore possible into questions which, up till now, have been closed to investigation, especially on the economic side, and this makes possible the elucidation of important scientific problems regarding railway operation (cost problems).

8. The wider general introduction of the perforated card system will provide advantageous possibilities for international co-operation, especially in the matter of reciprocal accounting and perhaps for the question of international traffic statistics. It is recommended that developments in this direction should be watched, and that later, at the appropriate time, they should form the subject for further discussion.

XV. — Co-operation of the staff towards increased efficiency and its participating in the profits.

SUMMARY.

The Fourth Section considers that, in spite of the efforts made by the Reporters, the information received from different Administations on the subject of Question XV is not conclusive.

In these circumstances the Section suggests to the Permanent Commission that the matter be referred back for further investigation and inclusion on the agenda for the next Congress, in the following terms, and expresses the hope that the next Congress, by taking into account the

data already received and the further information which will be collected, will be in a position to make suitable recommendations :

Participation of the staff in the results of working, under the various aspects of the problem of treatment, during each year, with the view of enlisting the men's close and harmonious co-operation in obtaining the maximum output and furthering the prosperity of the undertaking, at the same time giving railway users the best possible transportation at minimum cost. Methods of every kind will be considered and particularly the following :

1. Methods of interesting the staff in the partial or complete results of railway working.

2. Co-operation of the staff in the working of the undertaking (setting up sectional councils and suggestion schemes, etc.).

3. Methods of binding the staff to the railway service (social work, pensions, housing schemes, medical benefits, insurance, etc.).

4. Technical instruction.

XVI. — Methods followed in training of staff, professional, technical and ordinary working grades.

SUMMARY.

The information furnished in reply to the questionnaire indicates that staff instruction is well organised on the majority of the Railways.

The following summary is submitted by the Section :

1. Railway Administrations should take particular care to select candidates possessing the necessary qualifications for the post to be filled. To this end candidates should be required to pass an examination in general knowledge, or furnish a school certificate. Special examinations, including psycho-technical tests, should, however, be instituted if necessary. Several Administrations have made use of such tests with very satisfactory results; their extension is recommended.

2. Preliminary instruction should be given before the appointees commence work. This instruction will, of course, vary in character and duration, for ordinary workmen, artisans and clerks. Most Administrations have made arrangements of this kind, particularly as regards apprenticeships. It is recommended that Administrations should take care to give their manual workers at least as good a training as that afforded by other industries in their respective countries.

It is also recommended that all Railway Administrations in countries where military service is obligatory should give priority to their ex-apprentices who, on the termination of their military service, submit applications for employment in any posts that may be vacant.

3. In view of the information furnished by the various Administrations and the trials already carried out, it is recommended that employees should be given regular and methodical instruction in regard to new regulations, new developments in their respective spheres of work, and be taught to carry out their work economically (*i. e.* obviating waste of time or materials), punctually, and with safety to themselves, the public, and the rolling stock, etc. The employees should be required to serve probationary

periods, either in technical schools, or by instruction at the stations, depots, etc., using travelling schools (wagons-écoles), magic lanterns, and the cinematograph. Good results have been obtained from instructional cinematographs, and their use is recommended.

It is strongly recommended that men who work alone should receive careful instruction, and further that practical training should be given as regards the steps to be taken in the event of accidents or other emergencies.

Furthermore, it is necessary to test the men from time to time to see that they have assimilated the knowledge imparted to them, and are making good use of it.

4. It is also recommended that support should be given, as far as possible, to private institutions which provide tuition for the men, and attention is drawn to methods of teaching by correspondence, which has been successfully adopted by some Administrations.

5. Finally, men of particular merit should have an opportunity of being tested in regard to their powers of judgment and ability to command, with a view to promotion to the higher grades.

SECTION V. — Light railways and colonial railways.

XVII. — Penetration railways.

Construction :

a) *Penetration railways in new countries;*

b) *Feeder railways in all countries.*

SUMMARY.

PART A.

It would appear from the remarks made during the discussion that it is desirable that there should be a uniform gauge for the penetration railways in each country.

PART B.

With a view to remedying the present situation of feeder railways, it is recommended :

1. That, while respecting the rights of capital invested, lines whose receipts are so inadequate that considerable deficits must result in the future, be closed down unless the State, Provinces, or Towns concerned will themselves cover such deficits with a view to conserving the national equipment;

2. That lines closed down be replaced by motor services;

3. That the working conditions of the remaining lines be improved with the financial assistance of the State, Provinces, or Municipalities concerned;

4. As regards the attitude to be adopted towards road transport competition the Section refers to the conclusions adopted in conjunction with Sections III and IV.

XVIII. — Improvements in the permanent way equipment of light railways.

SUMMARY.

Axle loads of the stock are increasing more and more, necessitating well made, dry, and well drained earthworths, and a

much stronger and more solid permanent way.

Any gauge of track can be suitable according to local circumstances.

Equally, the choice of traction is a matter of convenience.

The Vignoles rail which is almost exclusively used in the lines laid beside high roads or on special earthworks, has the following average characteristics :

Gauge of track 1.435 m. (4 ft. 8 1/2 in.); height 140 mm. (5 1/2 inches); width 130 mm. (5 1/8 inches); head 60 mm. (2 3/8 inches), of an average linear weight of 38 kgr. (76.6 lb. per yard). Metre gauge : height 113 mm. (4 7/16 inches); width 90 mm. (3 1/2 inches); head 45 mm. (1 3/4 inches) of an average linear weight of 23 kgr. (46.4 lb. per yard) for the lines worked by steam, and of 125 mm. (5 inches) height, 105 mm. (4 1/8 inches) width, 57 mm. (2 1/4 inches) head, of an average linear weight of 32 kgr. (64.5 lb. per yard) for those worked electrically.

The length of the rails varies generally between 9 and 18 m. (29 ft. 6 3/8 in. and 59 ft. 5/8 in.) with a tendency towards the latter figure.

There is a marked preference for leaving the top of the sleepers free from ballast in view of the easier inspection and maintenance of the rail fastenings.

The choice of the kind of ballast is chiefly guided by economic reasons, although it is recognized that broken stone constitutes the best ballast.

Corrugated wear of rails only shows itself to a small extent on light railways. The remedy for this trouble can be found in the use of a good and homogeneous steel with a high tensile strength, a high elastic limit and the highest possible elongation. These different characteristics must be in suitable proportions to each other.

The laying of the track is done with opposite joints on the straight, staggered joints being used only when laying in curves of a radius generally smaller than 100 m. (5 chains).

Creep is hardly apparent in light railways. It is overcome either by the fixing of angle fishplates to the sleepers, or by stirrups which are fixed to the rails and the sleepers, or simply by stirrups against the heads of the coachscrews.

Frequently, the rails are laid at an inclination on the sleepers. This cant is obtained either by adzing the sleepers or by the shape of the sole plate or the chair. The first mentioned system is, however, the more generally used.

The fish plates of the rails are becoming simpler and generalized by the angle fishplate with four or six bolts; the loosening of these is chiefly prevented by spring washers, Grover type, or by tension plates.

Grooved or twin rails are used on the inner line of curves of a small radius. In this case the use in the outer line, of rails made of high tensile steel or special steels (manganese and chrome-nickel) is recommended.

Barberot keys can be used with economy on the outer rails of small curves.

The use of sleepers is general. Sleepers of oak, or pine impregnated with creosote, are the most used.

The rails are fastened to the wooden sleepers by means of coachscrews either direct or in conjunction with steel sole plates, without marked preference for either system.

When metal sleepers or ferro-concrete sleepers are used, the fastening of the rail is usually by means of clips and bolts.

The metal sleeper has advantages as regards duration and the security of the

fastenings; it is not however extensively used.

Concrete sleepers are being increasingly used, although they are costly and rather difficult to handle. The type consisting of two supports with large bearing surface joined by a small metal tie bar or by a ferro-concrete bar is generally preferred. It gives very encouraging results.

The welding of rails is not yet general practice.

Experiments made on a large-scale and of long duration show, however, the considerable advantages which can be obtained therefrom and encourage the development of its use.

Thermit welding has up to now only been employed for new lines; arc welding for old rails, repairs to points and crossings and building up of rail ends.

The process generally adopted when electrically welding rails consists in welding the fishplates of the rails, to stiffen up the joint by a plate welded under the foot and to weld the heads of the rails together.

Electric welding of the rails end to end without fishplates is, however, developing, and it would be interesting to see it continued in view of the encouraging results obtained during the experiments.

The limit, as regards length, of the parts of the line to be welded on special site or beside high roads is a matter of the temperature fluctuations in the district. For a temperature fluctuation of 60° C. (108° F.) the welded length can go up to 60 m. (197 feet) without inconvenience.

The use of heat treated cast steel in the manufacture of crossings is developing and gives very satisfactory results.

The experiments with special manganese or chrome-nickel steel for the manufacture of parts subjected to much strain (crossings and crossovers) have given entire satisfaction from the economic point of view as well as from that of wear.

XIX. — Electrification of secondary lines.

SUMMARY.

1. From the technical point of view, the railway operators have merely to make their selection, single phase current and high tension continuous current with overhead equipment having demonstrated their suitability whilst the principal firms supply perfectly satisfactory equipment.

2. Electrification of the main lines, and that of large areas by utilising natural motive forces and the recent improvements in mercury vapour rectifiers have facilitated the use of electric traction, particularly in the case of high tension continuous current, which has been made possible by the use of motors with commutating poles.

3. From the economic standpoint, however, electrification is generally only justifiable in the case of lines which possess features favourable to the system (cheap current, dear coal, sufficiently heavy passenger traffic, difficult conditions, necessity of meeting competition) and, above all, in the case of new lines.

4. Nevertheless, especially in new countries, the general interest may lead to the adoption of solutions which are not fully justified from the point of view of the return on the invested capital, but necessary for the development of the country. In such cases it may be in the interest of the community to cover the expenses of electrification out of the national or provincial budgets, so that the burden of those expenses will then in part fall upon the tax-payers, and not on the users

alone. This, moreover, is the case with roads, canals, etc.

5. When it is desired to avoid the installation of contact lines, the problem may be solved either by the electrification of rolling stock only, or by the use of rail motor vehicles.

XX. — Rail motor vehicles.

SUMMARY.

From the three reports presented it appears that :

1. In France, up to the present, is has been the general practice to manufacture light rail motor vehicles fitted with petrol engines, the Diesel engine having so far been little used owing to its high weight and cost.

2. In the other countries of Europe two types of internal combustion motor vehicles are in use :

A light type with a power of less than 100 H. P. usually fitted with a petrol engine and with mechanical transmission;

A heavy type of 180 to 250 H. P. with Diesel engine and with electric transmission.

In Europe use is also made of accumulator motor vehicles and internal combustion vehicles using producer gas.

3. Throughout the rest of the world all these types are found, with a strongly marked tendency in the United States and Canada to very high power, using Diesel engines with electric transmission.

The reports unanimously agree in stating that when the power exceeds 150 H. P., electric transmission is essential, and all find an appreciable saving in the use of rail motor coaches.

To summarize, it may be stated that :

Wherever traffic permits of the substitution of a motor vehicle for a steam train, experience shows that the substitution is financially an advantage, and this advantage will become more appreciable when the tests at present in progress with new fuels (heavy oil, charcoal, etc.), and even with other sources of energy, such as electric accumulators, have confirmed the results achieved to date.

Further, the Congress expresses the hope that manufacturers will produce standardized types, thereby reducing the first cost, which up to the present has been so high as to prevent the general adoption of those rail motor vehicles the use of which is really economical.

NEW BOOKS AND PUBLICATIONS.

[385 .(09 (.51)]

Report on progress in Manchuria 1907-1928. The South Manchuria Railway. — One volume of 238 pages with map and numerous illustrations. — 1929. Published by the South Manchuria Railway, Dairen.

The object of this book is to show the considerable economic development which has taken place in Manchuria during the last twenty years. The progress achieved in the agricultural, industrial and commercial spheres has only been possible thanks to the development of the railways and, accordingly, the first part of the report is devoted to a history of the railways and a description of their organisation and present situation.

The Manchurian railways have a total length of more than 3 000 miles, about half of which is owned by China, a third by Russia and the remainder by Japan. The *South Manchuria Railway* in particular, which passes through the heart of this great country, with a terminus at the recently improved port of Dairen, and is linked up with the lines which run across China proper and Korea and westwards towards Europe, has been an important instrument in increasing the prosperity of the agriculture and international trade of Manchuria.

The South Manchuria Railway system is operated by a Company constituted on the intervention and with the co-operation of the Japanase Government, which possessed proprietary rights over the railways and coal mines. The book describes in detail the constitution of the company, its administration and financial organisation, its financial policy, the nature and the development of the traffic, and the working results, which reveal a flourishing situation.

The other chapters of the book are devoted to an analysis of the progress achieved in commerce, agriculture, mining, forestry, fishing, manufactures, monetary organisation, etc.

In an early chapter we are given an insight into the political events which have led up to the present situation, and an appendix contains the text of the more important diplomatic documents, treaties and conventions affecting the railways.

[621 .138 .5 (.42]

2. — **Reorganisation of Crewe Locomotive Works, London Midland and Scottish Railway.** — One volume of 120 pages with numerous illustrations and plates. — 1929, London. Published by *The Railway Engineer*, 33, Tothill street, S. W. 1. (Price : 15 sh. nett)

The Crewe Locomotive Works of the London Midland & Scottish Railway have recently undergone a complete reorganisation. The object was to increase output and to reduce the periods during which locomotives are immobilised for repairs. The works are now in a position to repair from 30 to 35 locomotives per week and to turn out 100 new locomotives per year.

The general method of working is that known as the « chain » system